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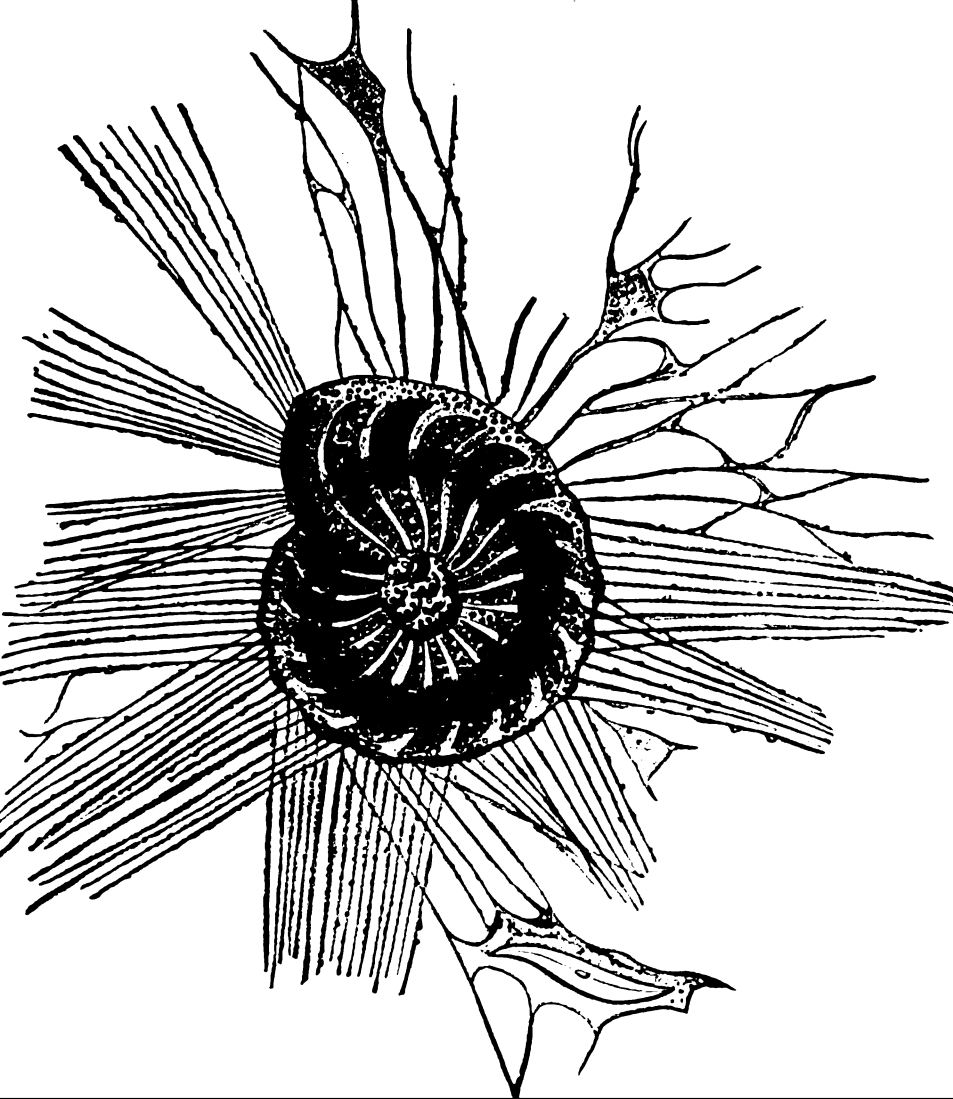
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Animals

David Starr Jordan

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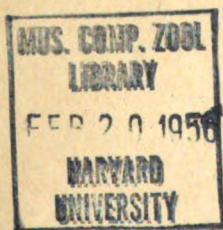
OF THE

Museum of Comparative Zoölogy

Penelope Barker Hayes.
Sparks and Highland Streets,
Cambridge,
Massachusetts.

10 October 1911.

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Red-faced cormorants (*Phalacrocorax urile*) on Walrus Island. Pribilof group. Photograph by HARRY CHICHESTER.

TWENTIETH CENTURY TEXT-BOOKS

ANIMALS

A TEXT-BOOK OF ZOOLOGY

BY

DAVID S. JORDAN, M. S., M. D., Ph. D., LL. D.

PRESIDENT OF LELAND STANFORD JUNIOR UNIVERSITY

VERNON L. KELLOGG, M. S.

PROFESSOR OF ENTOMOLOGY IN LELAND STANFORD JUNIOR UNIVERSITY

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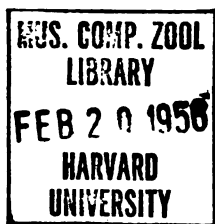
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ANIMALS

A TEXT-BOOK OF ZOOLOGY

PUBLISHERS' NOTE

THIS volume comprises *Animal Life* and *Animal Forms*, each of which is designed for schools that assign but a half year to Zoology. The two are issued in this form to meet more satisfactorily the requirements of normal schools and all higher schools that give a full year to the subject. It is believed that it will be found a very desirable text, also, for an elementary course in colleges.

The prefaces of the two sections of the book explain the plan, scope, and purpose of each. If preferred, the second part of this volume, *Animal Forms*, treating the morphological side of the subject, can be first taken up; or portions of each may be chosen and arranged in any order that may best suit the teacher's purposes. The first part, *Animal Life*, gives the ecological features of the subject special prominence.

Full indexes will be found at the end of each section.

TWENTIETH CENTURY TEXT-BOOKS

ANIMAL LIFE

A FIRST BOOK OF ZOÖLOGY

BY

DAVID STARR JORDAN, PH. D., LL. D.

PRESIDENT OF LELAND STANFORD JUNIOR UNIVERSITY

AND

VERNON L. KELLOGG, M. S.

PROFESSOR IN LELAND STANFORD JUNIOR UNIVERSITY



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1911

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P R E F A C E

THE authors present this book as an elementary account of animal ecology—that is, of the relations of animals to their surroundings and their responsive adaptation to these surroundings. The book takes the observer's point of view, who is especially concerned with the reasons for the varied structure and habits of animals. To understand how naturally and inevitably all animal form, habit, and life are adapted to the varied circumstances and conditions of animal existence should be the motive of the beginner in this fascinating study. The greatest facts of life, except that of life itself, are seen in the marvelously perfect methods which Nature has adopted in the structure and habits of animals. The keen observation of a fact should lead the student to inquire into the significance of that fact. The veriest beginner can be, and ought to be, an independent observer and thinker. In the study of zoölogy that phase which treats of the why and how of animal form and habit not only absorbs the attention of the most advanced modern scholars of biology, but should also appeal most strongly to the beginner. The beginner and the most enlightened thinker in zoölogy should each have the same point of view. With this belief in mind the authors have tried to put into simple form the principal facts and approved hypotheses upon which the modern conceptions of animal life are based.

It is unnecessary to say that this book depends for its

v

best use on a basis of personal observational work by the student in laboratory and field. Without independent personal work of the student little can be learned about animals and their life that will remain fixed. But present-day teachers of biology are too well informed to make a discussion of the methods of their work necessary here. As a matter of fact, the methods of the teacher depend so absolutely on his training and individual initiative that it is not worth while for the authors to point out the place of this book in elementary zoological teaching. That the phase of study it attempts to represent should have a place in such teaching is, of course, their firm belief.

The obligations of the authors for the use of certain illustrations are acknowledged in proper place. Where no credit is otherwise given, the drawings have been made by Miss Mary H. Wellman or by Mr. James Carter Beard, and the photographs have been made by the authors or under their direction.

DAVID STARR JORDAN,
VERNON LYMAN KELLOGG.

NOTE.—After the pages of the book were cast, it was thought that a transposition of Chapters III and IV would present a more logical arrangement, and teachers are advised to omit in their study scheme Chapter III until Chapter IV is completed.

D. S. J.
V. L. K.

CONTENTS

CHAPTER	PAGE
I.—THE LIFE OF THE SIMPLEST ANIMALS	1
The simplest animals, or Protozoa, 1.—The animal cell, 2.— What the primitive cell can do, 5.—Amœba, 5.—Paramœcium, 9. —Vorticella, 12.—Marine Protozoa, 15.—Globigerinæ and Radi- laria, 16.—Antiquity of the Protozoa, 20.—The primitive form, 20.—The primitive but successful life, 21.	
II.—THE LIFE OF THE SLIGHTLY COMPLEX ANIMALS	24
Colonial Protozoa, 24.—Gonium, 25.—Pandorina, 26.—Eudo- rina, 27.—Volvox, 28.—Steps toward complexity, 30.—Individual or colony, 31.—Sponges, 32.—Polyps, corals, and jelly-fishes, 37. —Hydra, 37.—Differentiation of the body cells, 41.—Medusæ or jelly-fishes, 41.—Corals, 43.—Colonial jelly-fishes, 45.—Increase in the degree of complexity, 48.	
III.—THE MULTIPLICATION OF ANIMALS AND SEX	50
All life from life, 50.—Spontaneous generation, 51.—The simplest method of multiplication, 53.—Slightly complex methods of multiplication, 54.—Differentiation of the reproductive cells, 55. —Sex, or male and female, 57.—The object of sex, 57.—Sex di- morphism, 58.—The number of young, 61.	
IV.—FUNCTION AND STRUCTURE	63
Organs and functions, 63.—Differentiation of structure, 64.— Anatomy and physiology, 64.—The animal body a machine, 65. —The specialization of organs, 66.—The alimentary canal, 66.— Stable and variable characteristics of an organ, 73.—Stable and variable characteristics of the alimentary canal, 73.—The mutual relation of function and structure, 77.	
V.—THE LIFE CYCLE	78
Birth, growth and development, and death, 78.—Life cycle of simplest animals, 78.—The egg, 79.—Embryonic and post-em- bryonic development, 80.—Continuity of development, 83.—De- velopment after the gastrula stage, 84.—Divergence of develop-	

ANIMAL LIFE

CHAPTER I

THE LIFE OF THE SIMPLEST ANIMALS

1. **The simplest animals, or Protozoa.**—The simplest animals are those whose bodies are simplest in structure and which do the things done by all living animals, such as eating, breathing, moving, feeling, and reproducing in the most primitive way. The body of a horse, made up of various organs and tissues, is complexly formed, and the various organs of the body perform the various kinds of work for which they are fitted in a complex way. The simplest animals are all very small, and almost all live in the water; some kinds in fresh water and many kinds in the ocean. Some live in damp sand or moss, and still others are parasites in the bodies of other animals. They are not familiarly known to us; we can not see them with the unaided eye, and yet there are thousands of different kinds of them, and they may be found wherever there is water.

In a glass of water taken from a stagnant pool there is a host of animals. There may be a few water beetles or water bugs swimming violently about, animals half an inch long, with head and eyes and oar-like legs; or there may be a little fish, or some tadpoles and wrigglers. These are evidently not the simplest animals. There will be many very small active animals barely visible to the unaided eyes. These, too, are animals of considerable complexity. But if a single drop of the water be placed

on a glass slip or in a watch glass and examined with a compound microscope, there will be seen a number of extremely small creatures which swim about in the water-drop by means of fine hairs, or crawl slowly on the surface of the glass. These are among our simplest animals. There are, as already said, many kinds of these "simplest animals," although, perhaps strictly speaking, only one kind can be called simplest. Some of these kinds are spherical in shape, some elliptical or football-shaped, some conical, some flattened. Some have many fine, minute hairs projecting from the surface; some have a few longer, stronger hairs that lash back and forth in the water, and some have no hairs at all. There are many kinds and they differ in size, shape, body covering, manner of movement, and habit of food-getting. And some are truly simpler than others. But all agree in one thing—which is a very important thing—and that is in being composed in the simplest way possible among animals.

2. **The animal cell.**—The whole body of any one of the simplest animals or Protozoa is composed for the animal's whole lifetime of but a single *cell*. The bodies of all other animals are composed of many cells. The cell may be called the unit of animal (or plant) structure. The body of a horse is complexly composed of organs and tissues. Each of these organs and tissues is in turn composed of a large number of these structural units called cells. These cells are of great variety in shape and size and general character. The cells which compose muscular tissue are very different from the cells which compose the brain. And both of these kinds of cells are very different from the simple primitive, undifferentiated kind of cell seen in the body of a protozoan, or in the earliest embryonic stages of a many-celled animal.

The animal cell is rarely typically cellular in character—that is, it is rarely in the condition of a tiny sac or box of symmetrical shape. Plant cells are often of this char-

acter. The primitive animal cell (Fig. 1) consists of a small mass of a viscid, nearly colorless, substance called *protoplasm*. This protoplasm is differentiated to form two parts or regions of the cell, an inner denser mass called the *nucleus*, and an outer, clearer, inclosing mass called the *cytoplasm*. There may be more than one nucleus in a cell. Sometimes the cell is inclosed by a *cell wall* which may be simply a tougher outer layer of the cytoplasm, or may be a thin membrane secreted by the protoplasm. In addition to the protoplasm, which is the fundamental and essential cell substance, the cell may contain certain so-called cell products, substances produced by the life processes of the protoplasm. The cell may thus contain water, oils, resin, starch grains, pigment granules, or other substances. These substances are held in the protoplasm as liquid drops or solid particles.

The protoplasm itself of the cell shows an obvious division into parts, so that certain parts of it, especially parts in the nucleus, have received names. The nucleus usually has a thin protoplasmic membrane surrounding it, which is called the *nuclear membrane*. There appear to be fine threads or rods in the nucleus which are evidently different from the rest of the nuclear protoplasm. These rods are called *chromosomes*. The cell is, indeed, not so simple as the words "structural unit" might imply, but science has not yet so well analyzed its parts as to warrant the transfer of the name structural unit to any single part of the cell—that is, to any lesser or simpler part of the animal body than the cell as a whole.

The protoplasm, which is the essential substance of the cell and hence of the whole animal body, is a substance



FIG. 1.—Blood cell of a crab (after HÄCKEL). Showing cytoplasm and nucleus (the large, inner, nearly circular spot) and granules of various substances lying in the cytoplasm.

of a very complex chemical and physical constitution. Its chemical structure is so complex that no chemist has yet been able to analyze it, and as the further the attempts at analysis reach the more complex and baffling the substance is found to be, it is not improbable that it may never be analyzed. It is a compound of numerous substances, some of these composing substances being themselves extremely complex. The most important thing we know about the chemical constitution of protoplasm is that there are always present in it certain complex albuminous substances which are never found in inorganic bodies. It is on the presence of these albuminous substances that the power of performing the processes of life depends. Protoplasm is the primitive basic life substance, but it is the presence of these complex albuminous compounds that makes protoplasm the life substance. A student of protoplasm and the fundamental life processes, Dr. Davenport, has said, "Just as the geologist is forced by the facts to assume a vast but not infinite time for earth building, so the biologist has to recognize an almost unlimited complexity in the constitution of the protoplasm." *

* The physical structure of protoplasm has been much studied, but even with the improved microscopes and other instruments necessary for the study of minute structure, naturalists are still very far from understanding the physical constitution of this substance. While the appearance of protoplasm under the microscope is pretty generally agreed on among naturalists, the interpretation of the kind of structure which is indicated by this appearance is not at all well agreed on. Protoplasm appears as a mesh work composed of fine granules suspended in a clearer substance, the spaces of the mesh work being composed of a third still clearer substance. Some naturalists believe, from this appearance, that protoplasm is composed of a clear viscous substance, in which are imbedded many fine granules of denser substance, and numerous large globules of a clearer, more liquid substance. Other naturalists believe that the fine spots which appear to be granules are simply cross sections of fine threads of dense protoplasm which lie coiled and tangled in the thinner, clearer protoplasm. And, finally,

3. **What the primitive cell can do.**—The body of one of the minute animals in the water-drop is a single cell. The body is not composed of organs of different parts, as in the body of the horse. There is no heart, no stomach; there are no muscles, no nerves. And yet the protozoan is a living animal as truly as is the horse, and it breathes and eats and moves and feels and produces young as truly as does the horse. It performs all the processes necessary for the life of an animal. The single cell, the single minute speck of protoplasm, has the power of doing, in a very simple and primitive way, all those things which are necessary for life, and which are done in the case of other animals by the various organs of the body.

4. **Amœba.**—The simple and primitive life of these Protozoa can be best understood by the observation of living individuals. In the slime and sediment at the bottom of stagnant pools lives a certain specially interesting kind of protozoan, the *Amœba* (Fig. 2). Of all the simplest animals this is as simple or primitive as any. The minute viscous particle of protoplasm which forms its body is irregular in outline, and its outline or shape slowly but constantly changes. It may contract into a tiny ball; it may become almost star-shaped; it may become elongate or flattened; short, blunt, finger-like projections called pseudopods extend from the central body mass, and these projections are constantly changing, slowly pushing out or

others believe that protoplasm exists as a foam work; that it is a viscous liquid containing many fine globules (the granule-appearing spots) of a liquid of different density and numerous larger globules of a liquid of still other density. It is a foam in which the bubbles are not filled with air, but with liquids of different density. This last theory of the structure of protoplasm is the one accepted by a majority of modern naturalists, although the other theories have numerous believers. But just as with what little we know of the chemical constitution of protoplasm, the little we know of its physical structure throws almost no light on the remarkable properties of this fundamental life substance.

drawing in. The single protoplasmic cell which makes up the body of the *Amæba* has no fixed outline; it is a cell without a wall. The substance of the cell or body is protoplasm, semiliquid and colorless. The changes in form of the body are the moving of the *Amæba*. By close watching it may be seen that the *Amæba* changes its position on the glass slip. Although provided with no legs or wings or

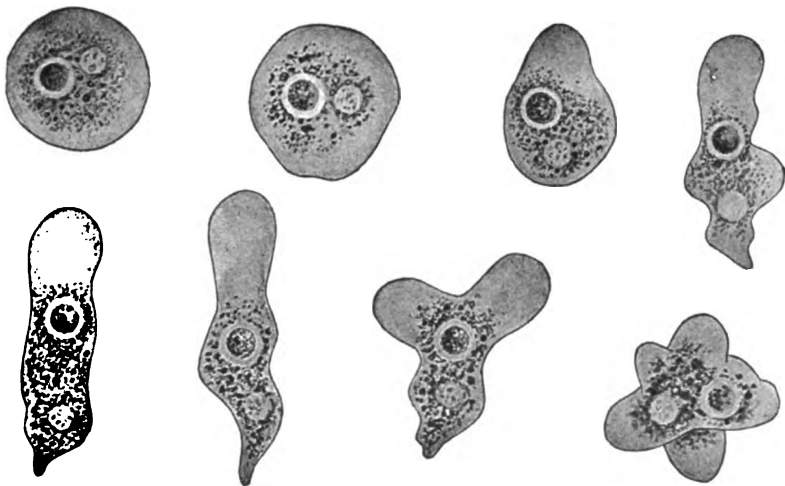


FIG. 2.—An *Amæba*, showing different shapes assumed by it when crawling.
—After VERWORN.

scales or hooks—that is, with no special organs of locomotion—the *Amæba* moves. There are no muscles in this tiny body; muscles are composed of many contractile cells massed together, and the *Amæba* is but one cell. But it is a contractile cell; it can do what the muscles of the complex animals do.

If one of the finger-like projections of the *Amæba*, or, indeed, if any part of its body comes in contact with some other microscopic animal or plant or some small fragment of a larger form, the soft body of the *Amæba* will be seen

to press against it, and soon the plant or animal or organic particle becomes sunken in the protoplasm of the formless body and entirely inclosed in it (Fig. 3). The absorbed particle soon wholly or partly disappears. This is the manner in which the *Amæba* eats. It has no mouth or



FIG. 3.—*Amæba* eating a microscopic one-celled plant.—After VERWORN.

stomach. Any part of its body mass can take in and digest food. The viscous, membraneless body simply flows about the food and absorbs it. Such of the food particles as can not be digested are thrust out of the body.

The *Amæba* breathes. Though we can not readily observe this act of respiration, it is true that the *Amæba* takes into its body through any part of its surface oxygen from the air which is mixed with water, and it gives off from any part of its body carbonic-acid gas. Although the *Amæba* has no lungs or gills or other special organs of respiration, it breathes in oxygen and gives out carbonic-acid gas, which is just what the horse does with its elaborately developed organs of respiration.

If the *Amæba*, in moving slowly about, comes into contact with a sand grain or other foreign particle not suitable for food, the soft body slowly recoils and flows—for the movement is really a flowing of the thickly fluid protoplasm—so as to leave the sand grain at one side. The *Amæba* feels. It shows the effects of stimulation. Its movements can be changed, stopped, or induced by mechanical or chemical stimuli or by changes in temperature. The

Amæba is irritable; it possesses irritability, which is sensation in its simplest degree.

If food is abundant the *Amæba* soon increases in size. The bulk of its body is bound to increase if new substance

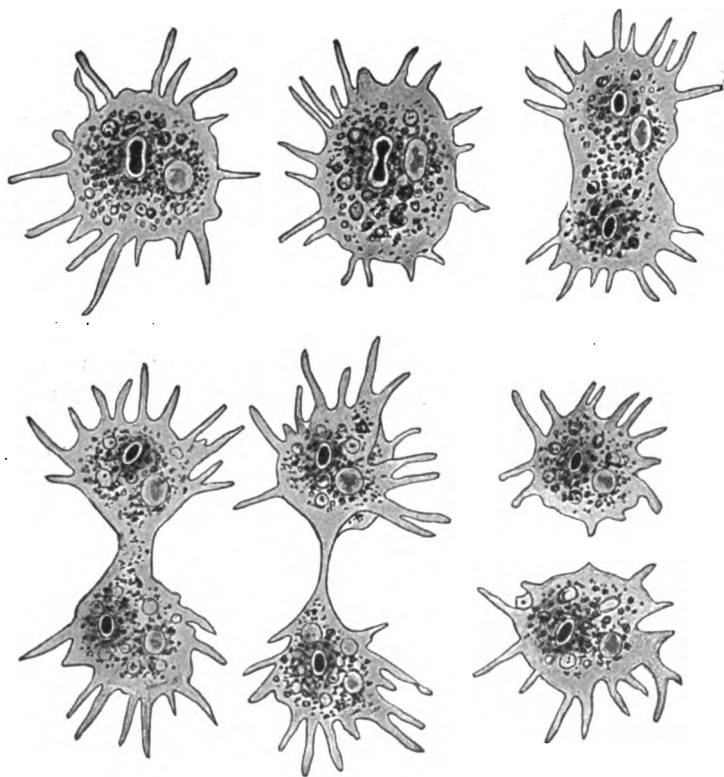


FIG. 4.—*Amæba polypodia* in six successive stages of division. The dark, white-margined spot in the interior is the nucleus.—After F. E. SCHULZE.

is constantly assimilated and added to it. The *Amæba* grows. But there seem to be some fixed limits to the extent of this increase in size. No *Amæba* becomes large. A remarkable phenomenon always occurs to prevent this.

An *Amœba* which has grown for some time contracts all its finger-like processes, and its body becomes constricted. This constriction or fissure increases inward, so that the body is soon divided fairly in two (Fig. 4). The body, being an animal cell, possesses a nucleus imbedded in the body protoplasm or cytoplasm. When the body begins to divide, the nucleus begins to divide also, and becomes entirely divided before the fission of the cytoplasm is complete. There are now two *Amœbæ*, each half the size of the original one; each, indeed, being actually one half of the original one. This splitting of the body of the *Amœba*, which is called fission, is the process of reproduction. The original *Amœba* is the parent; the two halves of the parent are the young. Each of the young possesses all of the characteristics and powers of the parent; each can move, eat, feel, grow, and reproduce by fission. It is very evident that this is so, for any part of the body or the whole body was used in performing these functions, and the young are simply two parts of the parent's body. But if there be any doubt about the matter, observation of the behavior of the young or new *Amœbæ* will soon remove it. Each puts out pseudopods, moves, ingests food particles, avoids sand grains, contracts if the water is heated, grows, and finally divides in two.

5. *Paramœcium*.—Another protozoan which is common in stagnant pools and can be readily obtained and observed is *Paramœcium* (Fig. 5). The body of the *Paramœcium* is much larger than that of the *Amœba*, being nearly one fourth of a millimeter in length, and is of fixed shape. It is elongate, elliptical, and flattened, and when examined under the microscope seems to be a very complexly formed little mass. The body of the *Paramœcium* is indeed less primitive than that of the *Amœba*, and yet it is still but a single cell. The protoplasm of the body is very soft within and dense on the outside, and it is covered externally by a thin membrane. The body is covered with short fine hairs or cilia,

which are fine processes of the dense protoplasm of the surface. There is on one side an oblique shallow groove

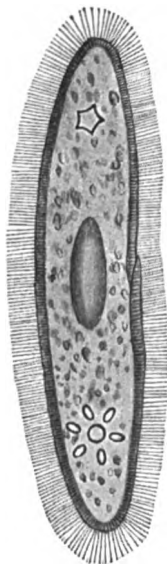


FIG. 5.—*Paramecium aurelia* (after VERWORN). At each end there is a contractile vacuole, and in the center is one of the nuclei.

which serves as a primitive sort of mouth or opening for the ingress of food. The *Paramecium* swims about in the water by vibrating the cilia which cover the body, and brings food to the mouth opening by producing tiny currents in the water by means of the cilia in the oblique groove. The food, which consists of other living Protozoa, is taken into the body mass only through the funnel-shaped opening, and that part of it which is undigested is thrust out always through a particular part of the body surface. (The taking in and ejecting of foreign particles can be seen by putting a little powdered carmine in the water.) Within the body there are two nuclei and two so-called pulsating vacuoles. These pulsating vacuoles (*Amœba* has one) seem to aid in discharging waste products from the body. When the *Paramecium* touches some foreign substance or is otherwise irritated it swims away,

and it shoots out from the surface of its body some fine long threads which when at rest are probably coiled up in little sacs on the surface of the body. When the *Paramecium* has taken in enough food and grown so that it has reached the limit of its size, it divides transversely into halves as the *Amœba* does. Both nuclei divide first, and then the cytoplasm constricts and divides (Fig. 6). Thus two new *Paramecia* are formed. One of them has to develop a new mouth opening and groove, so that there is in

the case of the reproduction of *Paramæcium* the beginnings of developmental changes during the course of the growth of the young. The young *Amœbæ* have only to add substance to their bodies, to grow larger, in order to be exactly like their parent.

The new *Paramæcia* attain full size and then divide, each into two. And so on for many generations. But it has been discovered that this simplest kind of reproduction can not go on indefinitely. After a number of generations the *Paramæcia*, instead of simply dividing in two, come together in pairs, and a part of one of the nuclei of each member of a pair passes into the body of and fuses with a part

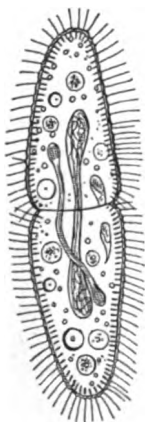


FIG. 6.—*Paramæcium putorinum* dividing. The two nuclei become very elongate before dividing.—After BÜTSCHLI.

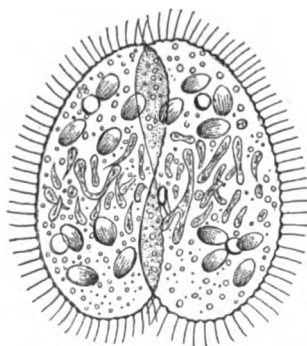


FIG. 7.—*Paramæcium caudatum*; two individuals separating after conjugation.

of one of the nuclei of the other member of the pair. In the meantime the second nucleus in each *Paramæcium* has broken up into small pieces and disappeared. The new nucleus composed of parts of the nuclei from two animals divides, giving each animal two nuclei just as it had before this extraordinary process, which is called conjugation, began (Fig. 7). Each *Paramæcium*, with its nuclei composed of parts of the nuclei from two distinct individuals,

now simply divides in two, and a large number of generations by simple fission follow.

Paramæcium in the character of its body and in the manner of the performance of its life processes is distinctly less simple than the *Amæba*, but its body is composed of a single structural unit, a single cell, and it is truly one of the "simplest animals."

6. **Vorticella.**—Another interesting and readily found protozoan is *Vorticella* (Fig. 8). While the *Amæba* can crawl and *Paramæcium* swim, *Vorticella*, except when very young,

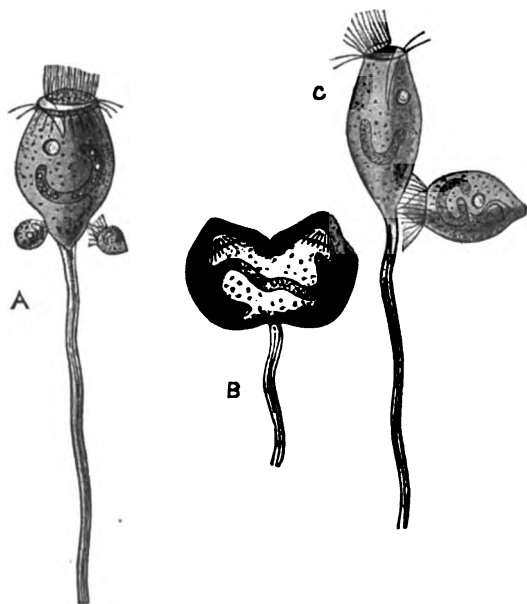


FIG. 8.—*Vorticella microstoma* (after STEIN). A, small, free-swimming individuals conjugating with a large, stalked individual; B, a stalked individual dividing longitudinally; C, after division is completed one part severs itself from the other, forms a ring of cilia, and swims away.

is attached by tiny stems to dead leaves or sticks in the water, and can change its position only to a limited extent.

The body is pear-shaped or bell-shaped, with a mouth opening at the broad end, and a delicate stem at the narrow end. This stem is either hard and stiff, or is flexible and capable of being suddenly contracted in a close spiral. In the body mass there is one pulsating vacuole and one nucleus. Usually many *Vorticellæ* are found together on a common stalk, thus forming a protozoan colony.

The life processes of *Vorticella* are of the simple kind already observed in *Amæba* and *Paramæcium*. *Vorticella* shows, however, some modifications of the process of reproduction which are interesting. The plane of division of *Vorticella* is parallel to the long axis of the pear-shaped body, so that when fission is complete there are two *Vorticellæ* on a single stalk. One of the two becomes detached, and by means of a circle of fine hairs or cilia which appear around its basal end leads a free swimming life for a short time. Finally it settles down and develops a stalk. *Vorticella* shows two kinds of fission—one the usual division into equal parts, and another division into unequal parts. In this latter kind, called reproduction or multiplication by budding, a small part of the parent body separates, develops a basal circle of cilia, and swims away. The process of conjugation also takes place among the *Vorticella*, but they are never two equal forms which conjugate, but always one of the ordinary stalked forms and one of the small free-swimming forms produced by budding.

Here, then, in the life of *Vorticella*, are new modifications of the life processes; but, after all, these life processes are very simply performed, and the body is like the body of the *Amæba*, a single cell. *Vorticella* is plainly one of "the simplest animals."

7. *Gregarina*.—A fourth kind of protozoan to which we can profitably give some special attention is *Gregarina* (Fig. 9), the various species of which live in the alimentary

canal* of crayfishes and centipeds and certain insects. *Gregarina* is a parasite, living at the expense of the host in whose body it lies. It has no need to swim about quickly,

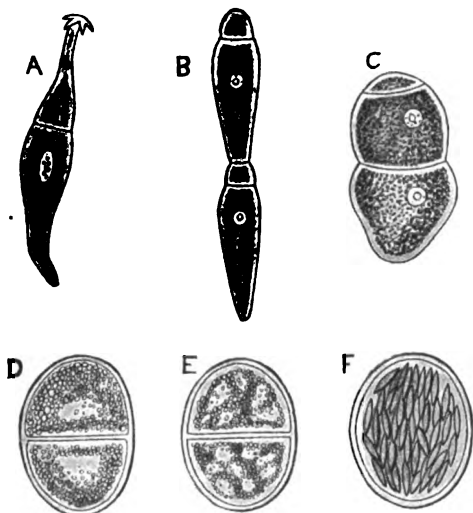


FIG. 9.—Gregarinidæ. A, a Gregarinid (*Actinocephalus oligacanthus*) from the intestine of an insect (after STEIN); B and C, spore forming by a Gregarinid (*Coccidium oviforme*) from the liver of a guinea-pig (after LEUCKART); D, E, and F, successive stages in the conjugation and spore forming of *Gregarina polymorpha* (after KOELLIKER).

and hence has no swimming cilia like *Paramœcium* and the young *Vorticella*. It does need to cling to the inner wall of the alimentary canal of its host, and the body of some species is provided with hooks for that purpose. The

* Specimens of *Gregarina* can be abundantly found in the alimentary canal of meal worms, the larvæ of the black beetle (*Tenebrio molitor*), common in granaries, mills, and brans. "Snip off with small scissors both ends of a larva, seize the protruding (white) intestine with forceps, draw it out, and tease a portion in normal salt solution (water will do) on a slide. Cover, find with the low power (minute, oblong, transparent bodies), and study with any higher objective to suit."—MURBACH.

food of *Gregarina* is the liquid food of the host as it exists in the intestine, and which is simply absorbed anywhere through the surface of the body of the parasite. There is no mouth opening nor fixed point of ejection of waste material, nor is there any contractile vacuole in the body.

In the method of multiplication or reproduction *Gregarina* shows an interesting difference from *Amœba* and *Paramœcium* and *Vorticella*. When the *Gregarina* is ready to multiply, its body, which in most species is rather elongate and flattened, contracts into a ball-shaped mass and becomes encysted—that is, becomes inclosed in a tough, membranous coat. This may in turn be covered externally by a jelly-like substance. The nucleus and the protoplasm of the body inside of the coat now divide into many small parts called spores, each spore consisting of a bit of the cytoplasm inclosing a small part of the original nucleus. Later the tough outer wall of the cyst breaks and the spores fall out, each to grow and develop into a new *Gregarina*. In some species there are fine ducts or canals leading from the center of the cyst through the wall to the outside, and through these canals the spores issue. Sometimes two *Gregarinae* come together before encystation and become inclosed in a common wall, the two thus forming a single cyst. This is a kind of conjugation. In some species each of the young or new *Gregarinae* coming from the spores immediately divides by fission to form two individuals.

8. **Marine Protozoa.**—If called upon to name the characteristic animals of the ocean, we answer readily with the names of the better-known ocean fishes, like the herring and cod, which we know to live there in enormous numbers; the seals and sea lions, the whales and porpoises, those fish-like animals which are really more like land animals than like the true fishes; and the jelly-fishes and corals and star-fishes which abound along the ocean's edge. But in naming only these we should be omitting certain animals which in point

of abundance of individuals vastly outnumber all other animals, and which in point of importance in helping maintain the complex and varied life of the ocean distinctly outclass all other marine forms. These animals are the marine Protozoa, those of the "simplest animals" which live in the ocean.

Although the water at the surface of the ocean appears clear, and on superficial examination devoid of life, yet a drop of this water taken from certain ocean regions examined under the microscope reveals the fact that this water is inhabited by Protozoa. Not only is the water at the very surface of the ocean the home of the simplest animals, but they can be found in all the water from the surface to a great depth beneath it. In a pint of this ocean water from the surface or near it there may be millions of these animals. In the oceans of the world the number of them is inconceivable. Dr. W. K. Brooks says that the "basis of all the life in the modern ocean is found in the micro-organisms of the surface." By micro-organisms he means the one-celled animals and the one-celled plants. For the simplest plants are, like the simplest animals, one-celled. "Modern microscopical research," he says, "has shown that these simple plants, and the Globigerinæ and Radiolaria [kinds of Protozoa] which feed upon them, are so abundant and prolific that they meet all demands and supply the food for all the animals of the ocean."

9. The Globigerinæ and Radiolaria.—The Globigerinæ (Fig. 10) and Radiolaria (Fig. 11) are among the most interesting of all the simplest animals. Their simple one-celled body is surrounded by a microscopic shell, which among the Globigerinæ is usually made of lime (calcium carbonate), in the case of Radiolaria of silica. These minute shells present a great variety of shape and pattern, many being of the most exquisite symmetry and beauty. The shells are usually perforated by many small holes, through which project long, delicate, protoplasmic threads. These

fine threads interlace when they touch each other, thus forming a sort of protoplasmic network outside of the shell. In some cases there is a complete layer of protoplasm—part of the body protoplasm of the protozoan—surround-

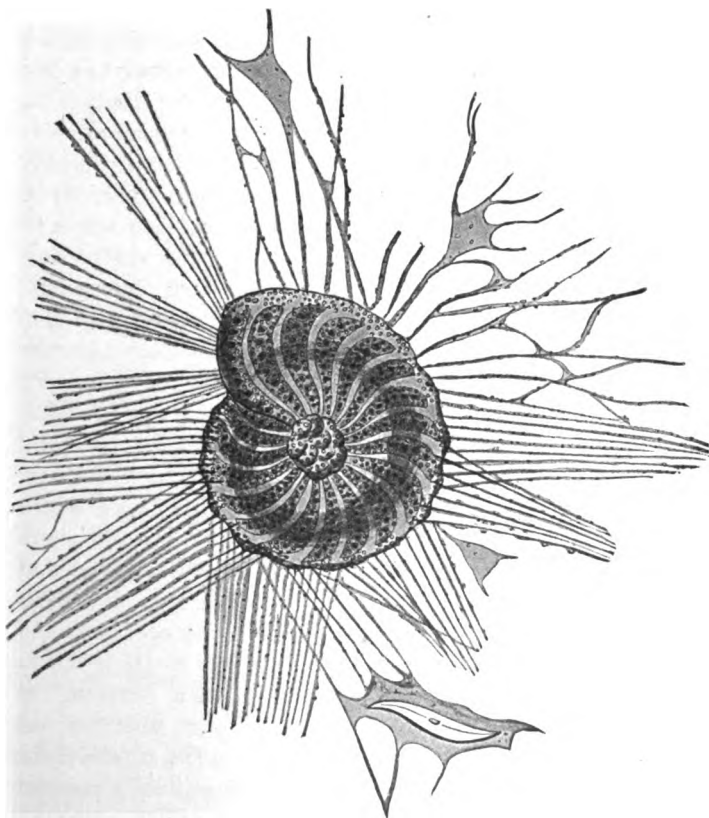


FIG. 10.—*Polystomella strigillata*, one of the Globigerinæ. —After MAX SCHULTZE.

ing the cell externally. The Radiolaria, whose shells are made of silica, possess also a perforated membranous sac called the central capsule, which lies imbedded in the protoplasm, dividing it into two portions, one within and

one outside of the capsule. In the protoplasm inside of the capsule lies the nucleus or nuclei; and from the protoplasm outside of the capsule rise the numerous fine, thread-like pseudopods which project through the apertures in the shell, and enable the animal to swim and to get food.

Most of the myriads of the simplest animals which swarm in the surface waters of the ocean belong to a few kinds of these shell-bearing Globigerinæ and Radiolaria. Large areas of the bottom of the Atlantic Ocean are covered with a slimy gray mud, often of great thickness, which is called globigerina-ooze, because it is made up chiefly of the microscopic shells of Globigerinæ. As death comes to the minute protoplasmic animals their hard shells sink slowly to the bottom, and accumulate in such vast quantities as to form a thick layer on the ocean floor. Nor is it only in present times and in the oceans we know that the Globigerinæ have flourished. All over the world there are thick rock strata which are composed chiefly of the fossilized shells of these simplest animals. Where the strata are made up exclusively of these shells the rock is chalk. Thus are composed the great chalk cliffs of Kent, which gave to England the early name of Albion, and the chalk beds of France and Spain and Greece. The existence of these chalk strata means that where now is land, in earlier geologic times were oceans, and that in the oceans Globigerinæ lived in countless numbers. Dying, their shells accumulated to form thick layers on the sea bottom. In later geologic ages this sea bottom has been uplifted and is now land, far perhaps from any ocean. The chalk strata of the plains of the United States, like those in Kansas, are more than a thousand miles from the sea, and yet they are mainly composed of the fossilized shells of marine Protozoa. Indeed, we are acquainted with more than twice as many fossil species of Globigerinæ as species living at the present time. The ancestors of these Globigerinæ, from which the present Globigerinæ differ but little, can be

traced far back in the geologic history of the world. It is an ancient type of animal structure.

The Radiolaria, too, which live abundantly in the present oceans, especially in the marine waters of the tropical and temperate zones, are found as fossils in the rocks from the time of the coal age on. The siliceous shells of the

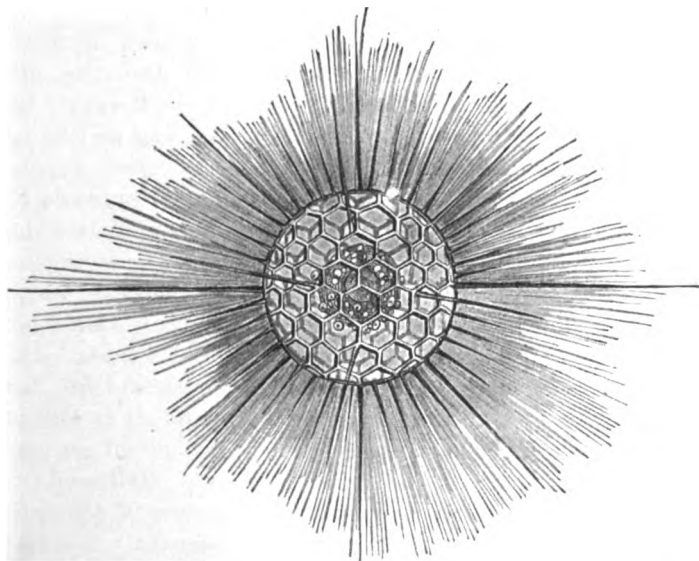


FIG. 11.—*Heliosphaera actinota* (after HAECKEL); a radiolarian with symmetrical shell.

Radiolaria sinking to the sea bottom and accumulating there in great masses form a radiolaria-ooze similar to the globigerinæ-ooze; and just as with the Globigerinæ, the remains of the ancient Radiolaria formed thick layers on the floor of the ancient oceans, which have since been uplifted and now form certain rock strata. That kind of rock called Tripoli, found in Sicily, and the Barbados earth from the island of Barbados, both of which are used

as polishing powder, are composed almost exclusively of the siliceous shells of ancient and long-extinct Radiolaria.

10. Antiquity of the Protozoa.—All the animals of the ocean depend upon the marine Protozoa (and the marine Protophyta, or one-celled plants) for food. Either they prey upon these one-celled organisms directly, or they prey upon animals which do prey on these simplest animals. The great zoölogist already quoted says: "The food supply of marine animals consists of a few species of microscopic organisms which are inexhaustible and the only source of food for all the inhabitants of the ocean. The supply is primeval as well as inexhaustible, and all the life of the ocean has gradually taken shape in direct dependence upon it." That is, the marine simplest animals are the only marine animals which live independently; they alone can live or could have lived in earlier ages without depending on other animals. They must therefore be the oldest of marine animals. By oldest we mean that their kind appeared earliest in the history of the world. As it is certain that marine life is older than terrestrial life—that is, that the first animals lived in the ocean—it is obvious that the marine Protozoa are the most ancient of animals. This is an important and interesting fact. Zoölogists try to find out the relationships and the degrees of antiquity or modernness of the various kinds of animals. We have seen that the Protozoa, those animals which have the simplest body structure and perform the necessary life processes in the simplest way, are the oldest, the first animals. This is just what we would expect.

11. The primitive form.—We find among the simplest animals a considerable variety of shape and some manifest variation in habit. But the points of resemblance are far more pronounced than the points of difference, and are of fundamental importance. The composition of the body of one cell, as opposed to the many-celled structure of the bodies of all other animals, is the fact to be most distinctly

emphasized. The shape of this one-celled body varies. With the most primitive or simplest of the "simplest animals," like *Amæba*, for example, there is no "distinction of ends, sides, or surfaces, such as we are familiar with in the higher animals. Anterior and posterior ends, right and left sides, dorsal and ventral surfaces are terms which have no meaning in reference to an *Amæba*, for any part of the animal may go first in locomotion, and when crawling the animal moves along on whatever part of its surface happens to be in contact with foreign bodies." The one shape most often seen among the Protozoa, or most nearly fairly to be called the typical shape, is the spherical or subspherical shape. Why this is so is readily seen. Most of the Protozoa are aquatic and free swimming. They live in a medium, the water, which supports or presses on the body equally on all sides, and the body is not forced to assume any particular form by the environment. The body rests suspended in the water with any part of its surface uppermost or any part undermost. As any part of the surface serves equally well in many of the Protozoa for breathing or eating or excreting, it is obvious that the spherical form is the simplest and most convenient shape for such a body. It is interesting to note that the spherical form is the common shape of the egg cell of the higher animals. Each one of the higher, multicellular animals begins life (as we shall find it explained in another chapter of this book) as a single cell, the egg cell, and these egg cells are usually spherical in shape. The full significance of this we need not now attempt to understand, but it is interesting to note that normally the whole body of the simplest animals is a single spherical cell, and that every one of the higher animals, however complex it may become by growth and development, begins life as a single spherical cell.

12. **The primitive but successful life.**—Living consists of the performing of certain so-called life processes, such as

eating, breathing, feeling, and multiplying. These processes are performed among the higher animals by various organs, special parts of the body, each of which is fitted to do some one kind of work, to perform some one of these processes. There is a division or assignment of labor here among different parts of the body. Such a division of labor, and special fitting of different parts of the body for special kinds of work does not exist, or exists only in slightest degree among the simplest animals. The *Amœba* eats or feels or moves with any part of its body; all of the body exposed to the air (air held in the water) breathes; the whole body mass takes part in the process of reproduction.

Only very small organisms can live in this simplest way. So all of the Protozoa are minute. When the only part of the body which can absorb oxygen is the simple external surface of a spherical body, the mass of that body must be very small. With any increase in size of the animal the mass of the body increases as the cube of the diameter, while the surface increases only as the square of the diameter. Therefore the part of the body (inside) which requires to be provided with oxygen increases more rapidly than the part (the outside) which absorbs oxygen. Thus this need of oxygen alone is sufficient to determine the limit of size which can be attained by the spherical or sub-spherical Protozoa.

That the simplest animals, despite the lack of organs and the primitive way of performing the life processes, live successfully is evident from their existence in such extraordinary numbers. They outnumber all other animals. Although serving as food for hosts of ocean animals, the marine Protozoa are the most abundant in individuals of all living animals. The conditions of life in the surface waters of the ocean are easy, and a simple structure and simple method of performance of the life processes are wholly adequate for successful life under these conditions.

That the character of the body structure of the Protozoa has changed but little since early geologic times is explained by the even, unchanging character of their surroundings. The oceans of former ages have undoubtedly been essentially like the oceans of to-day—not in extent and position, but in their character of place of habitation for animals. The environment is so simple and uniform that there is little demand for diversity of habits and consequent diversity of body structure. Where life is easy there is no necessity for complex structure or complicated habits of living. So the simplest animals, unseen by us, and so inferior to us in elaborateness of body structure and habit, swarm in countless hordes in all the oceans and rivers and lakes, and live successfully their simple lives.

CHAPTER II

THE LIFE OF THE SLIGHTLY COMPLEX ANIMALS

13. Colonial Protozoa.—When one of the simplest animals multiplies by fission, the halves of the one-celled body separate wholly from each other, move apart, and pursue their lives independently. The original parent cell divides to form two cells, which exist thereafter wholly apart from each other. There are, however, certain simple animals which are classed with the Protozoa, which show an interesting and important difference from the great majority of the simplest animals. These are the so-called colony-forming or colonial Protozoa.

These colonial Protozoa belong to a group of organisms called the * *Volvocinæ*. The simplest of the *Volvocinæ* are single cells, which live wholly independently and are in structure and habit essentially like the other Protozoa we have studied. They have, however, imbedded in the one-celled body a bit of chlorophyll, the green substance which gives the color to green plants and is so important in their physiology. In this respect they differ from the other Protozoa. Among the other *Volvocinæ*, however, a few or many cells live together, forming a small colony—that is,

* These colonial organisms, the *Volvocinæ*, are the objects of some contention between botanists and zoölogists. The botanists call them plants because they possess a cellulose membrane and green chromatophores, and exhibit the metabolism characteristic of most plants; but most zoölogists consider them to be animals belonging to the order *Flagellata* of the Protozoa. In the latest authoritative text-book of zoölogy, that of Parker and Haswell (1897), they are so classed.

there is formed a group of a few or many cells, each cell having the structure of the simpler unicellular forms. These cells are held together in a gelatinous envelope, and the mass is usually spherical in shape. In most of the colonies each of the cells possesses two or three long, protoplasmic, whiplash-like hairs, called flagella, and by the lashing of these flagella in the water the whole group swims about.

14. Gonium.—If, when one of the simplest animals divided to form two daughter cells, these two cells did not move apart, but remained side by side and each divided to form two more, and each of these divided to form two more, and these eight divided each into two, each cell complete and independent but all remaining together in a group—if this process should take place we should have produced a group or colony of sixteen cells, each cell a complete animal capable of living independently like the other simplest animals, but all holding together to form a tiny, flat, plate-like colony. Now, this is precisely what takes place

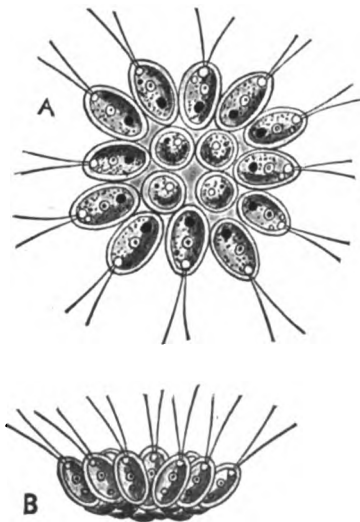


FIG. 12.—*Gonium pectorale* (after STEIN). A, colony seen from above; B, colony seen from the side.

in the case of those colonial Protozoa belonging to the genus *Gonium* (Fig. 12). When the mother cell of *Gonium* divides, the daughter cells do not swim apart, but remain side by side, and by repeated fission, until there are sixteen cells side by side, the colony is formed. Each cell of the

colony eats and breathes and feels for itself; each can and does perform all the processes necessary to keep it alive. When ready to multiply, the sixteen cells of the *Gonium* colony separate, and each cell becomes the ancestor of a new colony.

15. **Pandorina.**—Another colony usually composed of sixteen cells is *Pandorina*, but the cells are arranged to form a spherical instead of a plate-like colony (Fig. 13). In *Pandorina morum* the colony consists of sixteen ovoid cells in a spherical jelly-like mass. Each cell has two flagella, and by the lashing of all the flagella the whole colony moves through the water. Food is taken by any of the cells, is assimilated, and the cells increase in size. When *Pandorina* is ready to multiply, each cell divides repeatedly until it has formed sixteen daughter cells. The inclosing gelatinous mass which holds the colony together dissolves,

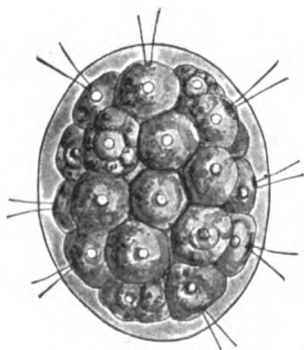


FIG. 13.—*Pandorina* sp. (from Nature). The cells composing the colony are beginning to divide to form daughter colonies.

and the daughter colonies become free and swim apart. Each colony soon grows to the size of the original colony. This kind of multiplication or reproduction may be continued for several generations. But it does not go on indefinitely. After a number of these generations has been produced by simple division, the cells of a colony divide each into eight instead of sixteen daughter cells. The daughter cells are not all of the same size, but the difference is hardly noticeable.

The eight cells resulting from the repeated division of one of the original cells separate and swim about independently by means of their flagella. If one of these cells comes near a similar free-swimming cell from another

colony, the two cells conjugate (Fig. 14)—that is, fuse to form a single cell. This new cell formed by the fusion of two, develops a tough enveloping membrane of cellulose and passes into what is called the "resting stage." That is, the cell remains dormant for a shorter or longer time. It may thus tide over a drought or a winter. It may become dry or be frozen, yet when suitable conditions of moisture or temperature are again present the outer wall breaks and the protoplasm issues as a large free-swimming cell, which soon divides into sixteen daughter cells which constitute a new colony.

16. *Eudorina*.—Another colonial protozoan which much resembles *Pandorina*, but differs from it in one interesting and suggestive thing, is *Eudorina*. In *Eudorina elegans* (Fig. 15) the colony is spherical and is composed of sixteen or thirty-two cells. Each of these cells can become the parent of a new colony by simple repeated division. But this simple mode of reproduction, just as with *Pandorina*, can not persist indefinitely. There must be conjugation. But the process of multiplication, which includes conjugation, is different from that process in *Pandorina*, in that in *Eudorina* the conju-

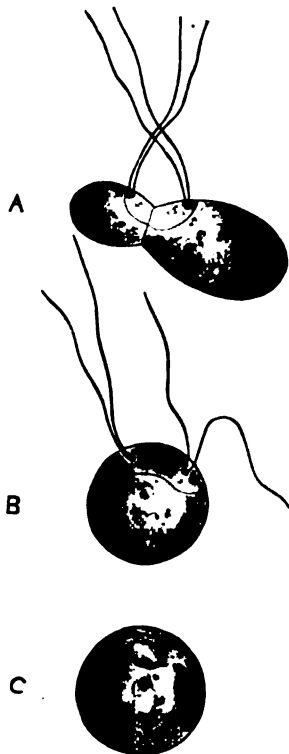


FIG. 14. — *Pandorina morum* (after GOEBEL). Three stages in the conjugation and formation of the resting spore. A, two cells just fused; B, the two cells completely fused, but with flagella still persisting; C, the resting spore.

gating cells are of two distinctly different kinds. When this kind of multiplication is to take place in the case of *Eudorina elegans*, to choose a common species, some of the cells of a colony divide into sixteen or thirty-two minute elongated cells, each provided with two flagella. These small cells escape

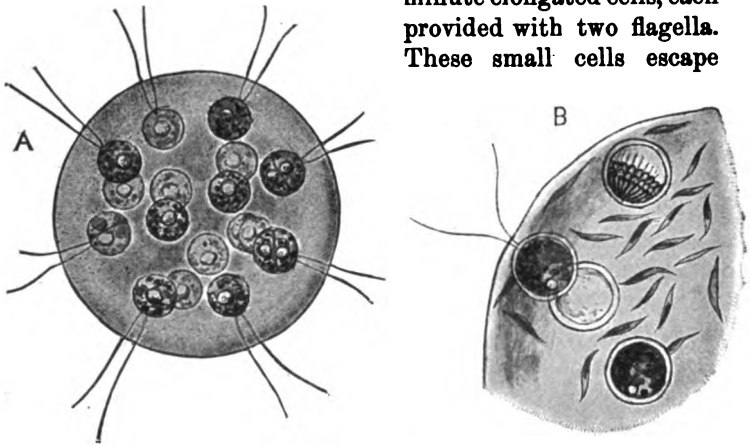


FIG. 15.—*Eudorina elegans*. A, a mature colony (from Nature); B, formation of the two kinds of reproductive cells.

from the envelope of the parent cell, remaining for some time united in small bundles. Other cells of the colony do not divide, but increase slightly in size and become spherical in shape. When a bundle of the small cells comes into contact with some of these large spherical cells the bundle breaks up, and conjugation takes place between the small flagellated free-swimming cells and the large non-flagellate spherical cells. Each new cell formed by the fusion of one of the small and one of the large cells develops a cellulose wall and assumes a resting stage. After a time from each of these resting spores a new colony of sixteen or thirty-two cells is formed by direct, repeated division.

17. **Volvox.**—Another interesting colonial protozoan is *Volvox*. The large spherical colonies of *Volvox globator*

(Fig. 16) are composed of several thousand cells, arranged in a single peripheral layer about the hollow center of the ball. The cells are ovoid, and each is provided with two long flagella which project out into the water. The lashing of the thousands of the flagella give the ball-like colony a rotary motion. The cells are held together by a jelly-like intercellular substance and are connected with each other by fine protoplasmic threads which extend from the body protoplasm of one cell to the cells surrounding it. When the colony is full grown and ready to reproduce itself certain cells of the colony undergo great changes. Some of them increase in size enormously, having reserve food material stored in them, and they may be called the egg cells of the colony. Reproduction may now occur by simple division of one of these great egg cells into many small cells, all held together in a common envelope. These form a daughter colony which escapes from the mother colony and by growth and further division comes to be a new full-sized colony. Or reproduction may occur in another, more complex, way. Certain cells of the colony

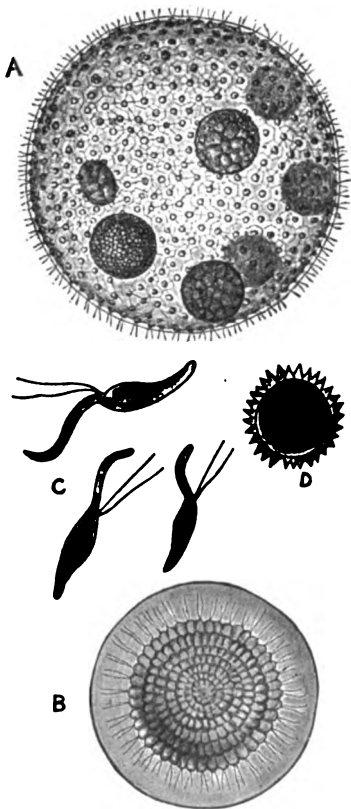


FIG. 16.—A, *Volvox minor*, entire colony (from Nature). B, C, and D, reproductive cells of *Volvox globator*.

divide into bundles of very small, slender cells, each of which is provided with flagella. The remaining cells of the colony (that is, those which have not swollen into egg cells or divided into many—sixty-four to one hundred and twenty-eight—minute, flagellate cells) remain unchanged for a while and finally die. They take absolutely no part in reproducing the colony. One of the minute free-swimming cells fuses with one of the enormous egg cells, the new cell thus formed being a resting spore. From this resting spore a new colony develops by repeated division.

18. **Steps toward complexity.**—Within the group of *Volvocinæ* there are plainly several steps on the way from simplicity of structure to complexity of structure. *Gonium*, *Pandorina*, *Eudorina*, and *Volvox* form a series proceeding from the simplest animals toward the complex animals. In *Gonium* the cells composing the colony are all alike in structure, and each one is capable of performing all the processes or functions of life. In *Pandorina* and *Eudorina* the cells are at first alike, but there is, as the time for reproduction approaches, a differentiation of structure; the cells of the colony, all of which take part in the process of reproduction, come to be in certain generations of two kinds—an inactive large kind which may be called the egg cells, and a small, active, free-swimming kind which seeks out and conjugates with, or, we may say, fertilizes the egg cells. In *Volvox* there is a new differentiation. Only certain particular and relatively few cells take part in reproducing the colony; most of the cells have given up the power or function of reproduction. These cells, when the time of multiplication comes, simply support the special reproductive cells. They continue to waft the great colony through the water by lashing their flagella; they continue to take in food from the outside. The reproductive cells devote themselves wholly to the business of producing new colonies, of perpetuating the species. And this matter of reproduction is less simple than in the other *Volvocinæ*.

At least there is much more difference between the two kinds of reproductive cells. The egg cells are comparatively enormous, and they are stored with a mass of food material. The fertilizing cells are very small, but very active and very different from the egg cells. We have in *Volvox* the beginnings of a distinct division of labor and an accompanying differentiation of structure. Certain cells of the colony do certain things, and are modified in structure to fit them specially for their particular duties. The steps from the simplest structure toward a complex structure are plainly visible.

19. **Individual or colony.**—Is the *Gonium* colony, the *Pandorina* colony, or the *Volvox* colony a group of several or many distinct organisms, or is it to be considered as a single organism? With *Gonium*, which we may call the simplest of these colonial organisms, the colony is composed of a few wholly similar cells or one-celled animals, each fully capable of performing all the life processes, each wholly competent to lead an independent life. In fact, each does, for part of its life, live independently, as we have already described. In the case of *Pandorina* and *Eudorina*, while all the cells are for most of the lifetime of the colony alike and each is capable of living independently, at the time of reproduction the cells become of two kinds. A difference of structure is apparent, and for the perpetuation of the species the co-operation of these different kinds of cells is necessary. That is, it is impossible for a single one of the members of the colony to reproduce the colony, except for a limited number of generations. With *Volvox* this giving up of independence on the part of the individual members of the colony is more marked. There is a real interdependence among the thousands of cells of the colony. The function of reproduction rests with a few particular cells, and for the perpetuation of the species there is demanded a co-operation of two distinct kinds of reproductive cells. The great majority of the cells take no part in reproduc-

tion. They can perform all the other life processes; they move the colony by lashing the water with their flagella; they take in food and assimilate it; they can feel. All the cells of the great colony, too, are intimately connected by means of protoplasmic threads. The protoplasm of one cell can mingle with that of another cell; food can go from cell to cell. The question whether the *Volvox* colony is a group of distinct organisms or is a single organism made up of cells among which there is a simple but obvious difference in structure and function; in other words, whether *Volvox* is a colony of one-celled animals, of Protozoa, or is a multicellular animal, one of the Metazoa (for so all the many-celled animals are called), is a difficult one to decide. Most zoölogists class the Volvocinæ with the Protozoa—that is, they incline to consider *Gonium*, *Pandorina*, *Volvox*, and the other Volvocinæ as groups or colonies of one-celled animals.

20. **Sponges.**—If the Volvocinæ be considered to belong to the Protozoa, the sponges are the simplest of all the many-celled animals. Sponges are not free-swimming animals, except for a short time in their young stage, but are fixed, like plants. They live attached to some solid substance on the sea bottom. They resemble plants, too, in the way in which the body is modified during growth by the environment. If the rock to which the young sponge is attached is rough and uneven, the body of the sponge will grow so as to fit the unevenness; if the rock surface is smooth, the body of the sponge will be more regular. Thus a sponge may be said to have no fixed shape of body; individuals of the same species of sponge differ much in form. The typical form of the sponges is that of a short cylinder or vase attached by one end and with the upper free end open (Fig. 17). Many individuals of one kind usually live together in a close group or colony, and they may be so attached to each other as to appear like a branching plant. This branching may be very diffuse, and the branches

may become so interwoven with each other as to form a very complex group. A sponge is composed of many cells arranged in three layers—that is, the body of a sponge is a cylinder closed at one end whose wall is composed of three layers of cells. The outer layer of cells is called the *ectoderm*, and the cells composing it are flat and are all closely attached to each other. The inner layer is called the *endoderm*, and its cells are thicker than those of the ectoderm; they are also closely attached to each other. Sometimes they are provided with flagella like the flagellate Protozoa. The flagella are, however, not for the purpose of locomotion, but for creating currents in the water, which bathes the interior of the open cylindrical body. The middle layer, called the *mesoderm*, is composed of numerous separate cells lying in a jelly-like matrix. From these mesoderm cells fine needles or spicules of lime or silica often project out through the ectoderm. These minute sponge spicules are of a great variety of shapes, and they form a sort of skeleton for the support of the soft body mass. All over the outer surface of the body are scattered fine openings or pores, which lead through the walls of the body into the inner cavity. This cavity is of course also connected with the outside by the large opening at the free or apical end of the body.

There is hardly any differentiation of parts among the



FIG. 17.—One of the simplest sponges, *Calcolynthus primigenius* (after HAECKEL). A part of the outer wall is cut away to show the inside.

sponges. As in the Protozoa, there are no special organs for the performance of special functions. The sponge feeds by creating, with its flagella, water currents which

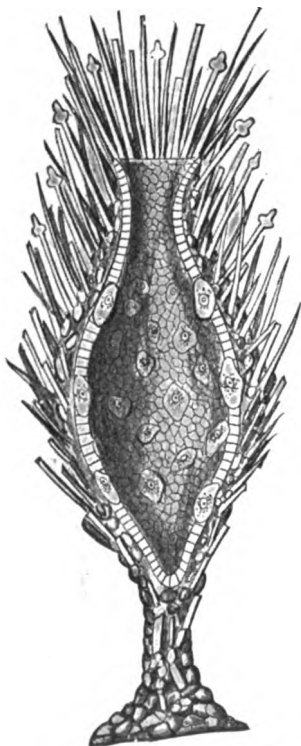


FIG. 18.—One of the simple sponges, *Prophysema primordiale* (after HAECKEL). The body is represented as cut in two longitudinally. The large cells of the inner layer are the egg cells.

flow in through the many fine pores of the body and out from the inner body cavity through the large opening at the free end of the body. These currents of water bear fine particles of organic matter which are taken up by the cells lining the pores and body cavity, and assimilated. There are no special organs of digestion. Each cell takes up food and digests it. The water currents also bring air to these same cells, and thus the sponge breathes. Although the sponge as a whole can not move, does not possess the power of locomotion, yet the protoplasm of the cells has the power of contracting, just as with the Protozoa, and the pores can be opened or closed by this cellular movement. Practically, thus, the only movements the sponge can make are the movements made by the individual cells.

Reproduction is accomplished by a process of division, or by a process of conjugation and subsequent division. In its simplest way multiplication takes place by a group of cells separating from the body of the parent sponge,

becoming inclosed in a common capsular envelope, and by repeated division and consequent increase in number of cells becoming a new sponge. This is reproduction by "budding." The "buds," or small groups of cells which separate from the parent sponge, are called *gemmules*. Reproduction in the more complex way occurs as follows: Some of the free amœboid cells of the mesoderm (the middle one of the three layers of the body wall) become enlarged and spherical in form. These are the egg cells. Other mesodermic cells divide into many small cells, which are oval with a long, tapering, tail-like projection. These cells are active, being able to swim by the lashing of the tapering tail. These are the fertilizing cells. The two kinds of reproductive cells may be formed in one sponge; if so, they are formed at different times. Or one sponge may produce only egg cells, another only fertilizing or, as they are called, sperm cells. Conjugation takes place between a sperm cell and an egg cell. That is, one of the small active sperm cells finds one of the large, spherical, inactive cells and penetrates into the protoplasm of its body. The two cells fuse and form a single cell, which may be called the fertilized or impregnated egg. This fertilized egg, remaining in the body mass of the parent sponge, divides repeatedly, the new cells formed by this division remaining together. The young or embryo sponge finally escapes from the body of the parent sponge, and lives for a short time as an active free-swimming animal. Its body consists of an oval mass of cells, of which those on one side are provided with cilia or swimming hairs. The cells of the body continue to divide and to grow, and the body shape gradually changes. The young sponge finally becomes attached to some rock, the body assumes the typical cylindrical shape, an aperture appears at the free end, and small perforations appear on the surface. The sponge becomes full grown.

Those of us who do not live in the vicinity of the sea-

shore where sponges are found can not observe the structure and life history of living specimens. There are, however, among the thousand and more kinds of sponges a few kinds that live in fresh water, and these are so widely spread over the earth that examples of them can be found in almost any region. They belong to the genus *Spongilla*, and thirty or more species or kinds of *Spongilla* are known. In standing or slowly flowing water, *Spongilla* grows erect and branching, like a shrub or miniature tree; in swift water it grows low and spreading, forming a sort of mat over the surface to which it is attached. Reproduction takes place very actively by the process of budding. The budded-off gemmules are spherical in shape, and the cells of each gemmule are inclosed in an envelope composed of siliceous spicules of peculiar shape. These gemmules are formed in the body substance of the parent sponge toward the end of the year, and are set free by the decaying of that part of the body of the parent sponge in which they lie. They sink to the bottom of the pond or brook, and lie there dormant until the following spring. Then they develop rapidly by repeated division of the cells and growth.

It is not the purpose here to describe the many and interesting kinds of sponges which inhabit the ocean. The sponge of the bathroom is simply the skeleton of a large sponge or group of sponges. The skeleton here is not composed of lime or silica, but of a tough, horny substance, which is secreted by cells of the mesodermal layer of the body wall of the sponge. This substance is called *spongin*, and is a substance allied to silk in its chemical composition. All the commercial sponges, the spongin skeletons, belong to one genus—*Spongia*. These sponges grow especially abundantly in the Mediterranean and Red Seas, and in the Atlantic Ocean off the Florida reefs, and on the shores of the Bahama Islands. The sponges are pulled up by divers, or by means of hooks or dredges. The

living matter soon dies and decays, leaving the horny skeleton, which when cleaned and trimmed is ready for use.

The most beautiful sponges are those with siliceous skeletons. The fine needles or threads of glass, arranged often in delicate and intricate pattern, make these sponges objects of real beauty.

21. **Polyps, corals, and jelly-fishes.**—The general or typical plan of body structure of those animals which come next in degree of complexity to the sponges can be best understood by imagining the typical cylindrical body of a sponge modified in the following way: The middle one of the three layers of the body wall not to be composed of cells in a gelatinous mass, but to be simply a thin non-cellular membrane; the body wall to be pierced by no fine openings or pores, so that the interior cavity of the body is connected with the outside only by the single large opening at the free end, and this opening to be surrounded by a circlet of arm-like processes or tentacles, continuations of the body wall and similarly composed. Such a body structure is the general or fundamental one for all polyps, corals, sea-anemones, and jelly-fishes. The variety in shape and the superficial modifications of this type-plan are many and striking; but, after all, the type-plan is recognizable throughout the whole of this great group of animals. Perhaps the simplest representative of the group is a tiny polyp which grows abundantly in the fresh-water streams and pools, and can be readily obtained for observation. It is called *Hydra*.

22. **Hydra.**—The body of *Hydra* (Fig. 19), which is very small and appears to the unaided eye as a tiny white or greenish gelatinous particle attached to some submerged stone, bit of wood, or aquatic plant, is a simple cylinder attached by one end to the stone or weed. The other free end is contracted so as to be conical, and it is narrowly open. Around the opening are six or eight small waving

tentacles. The wall of the cylinder is composed of an outer and an inner layer of cells and a thin non-cellular membranous layer between them. The tentacles are hollow and are simple extensions of the body wall. The cells of the outer layer, or ectoderm, are not all alike. Some are smaller than the others and appear to be crowded in

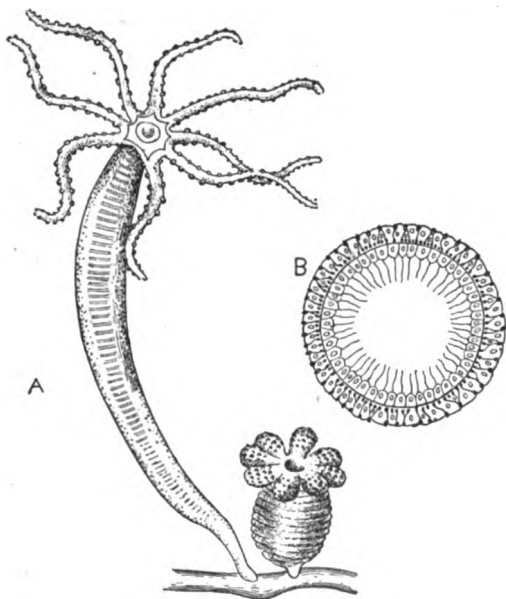


FIG. 19.—The fresh-water polyp, *Hydra vulgaris*. A, in expanded condition, and in contracted condition; B, cross section of body, showing the two layers of cells which make up the body wall.

between the bases or inner ends of the larger ones. The inner ends of the large cells are extended as narrow-pointed prolongations directed at right angles with the rest of the cell. These processes are very contractile and are called muscle processes. Each one is simply a continuation of the protoplasm of the cell body, which is especially contractile. Some of the smaller ectoderm cells are very

irregular in shape and possess specially large nuclei. These cells are more irritable or sensitive than the others and are called nerve cells. The ectoderm cells of the base or foot of the *Hydra* are peculiarly granular, and secrete a sticky substance by which the *Hydra* holds fast to the stone or weed on which it is found. These cells are called gland cells. Imbedded in many of the larger ectoderm cells, especially those of the tentacles, are small oval sacs, in each of which lies folded or coiled a fine long thread. When the tentacles touch one of the small animals which serve *Hydra* as food, these fine threads shoot out from their sacs and so poison or sting the prey that it is paralyzed. The tentacles then contract and bend inward, forcing the captured animal into the mouth opening in the center of the circle of tentacles. Through the mouth opening the prey enters the body cavity of *Hydra* and is digested by the cells lining this cavity. These cells belonging to the inner layer of the body wall or endoderm are mostly large, and each contains one or more contractile vacuoles. From the free ends—the ends which are next to the body cavity—of these cells project pseudopods or fine flagella. These projections are constantly changing: now two or three short, blunt pseudopods are projecting into the body cavity; now they are withdrawn, and a few fine, long flagella are projected. In addition to these cells there are in the endoderm, especially abundant near the mouth opening and wholly lacking in the tentacles and at the base of the body, many long, narrow, granular cells. They are gland cells which secrete a digestive fluid. The food captured by the tentacles and taken in through the mouth opening disintegrates in the body cavity, or digestive cavity, as it may be called. The digestive fluid secreted by the gland cells of the endoderm acts upon it, so that it becomes broken into small parts. These particles are probably seized by the pseudopods of the other endoderm cells and are taken into the body protoplasm

of these cells. The ectoderm cells do not take food directly, but receive nourishment only through the endoderm cells.

Hydra is not permanently attached. It holds firmly to the submerged stone or weed by means of the sticky secretion from the ectodermal gland cells of its base, but it can loosen itself, and by a slow creeping or gliding move along the surface of the stone to another spot. Even when attached, the form of the body changes; it extends itself longitudinally, or it contracts into a compact globular mass. The tentacles move about in the water, and are continually contracting or extending.

Like *Volvox* and the sponges, those other slightly complex animals we have already considered, *Hydra* has two methods of multiplication. In the simpler way, there appears on the outer surface of the body a little bud which is composed, at first, of ectoderm cells alone; but soon it is evident that it is a budding, or outpushing, of the whole body wall, ectoderm, endoderm, and middle membrane. In a few hours the bud has six or eight tiny, blunt tentacles, a mouth opening appears at the free end, and the little *Hydra* breaks off from the parent body and leads an independent existence. In the more complex way, two kinds of special reproductive cells are produced by each individual, viz., large, inactive, spherical egg cells, and small, active sperm cells, each with an oval part or head (consisting of the nucleus) and a slender, tapering tail-like part (consisting of the cytoplasm). The egg cell lies inclosed in a layer of thin, surrounding cells, which compose a capsule for it. When the egg cell is ready for fertilization this capsule breaks, and one of the active sperm cells finds its way to and fuses with the egg cell. The fertilized egg cell now divides into several cells, which remain together. The outer ones form a hard capsule, and thus protected the embryo falls to the bottom, and after lying dormant for awhile develops into a *Hydra*.

23. Differentiation of the body cells.—In *Hydra* we have the beginnings of complexity of structure carried a step further than in the sponges. The division of labor among the cells composing the body is more pronounced, and the structural modification of the different cells to enable them better to perform their special duties is obvious. Some of the cells of the body specially devote themselves to food-taking; some specially to the digestion of the food; some are specially contractile, and on them the movements of the body depend, while others are specially irritable or sensitive, and on them the body depends for knowledge of the contact of prey or enemies. In the lasso cells—those with the stinging threads—there is a very wide departure from the simple primitive type of cells. There is in *Hydra* a manifest differentiation of the cells into various kinds of cells. The beginnings of distinct tissues and organs are foreshadowed.

The individuals of *Hydra* live, usually, distinct from each other. There is no tree-like colony, as with the sponges. But most of the other polyps do live in this colonial manner. The new polyps which develop as buds from the body of the parent do not separate from the parent, but remain attached by their bases. They, in turn, produce new polyps which remain attached, so that in time a branching, tree-like colony is formed.

24. Medusæ or jelly-fishes.—Most of the other polyps differ from *Hydra* also in producing, in addition to ordinary polyp buds, buds which develop into bell-shaped structures called *medusæ* (Fig. 20). These medusæ consist of a soft gelatinous bell- or umbrella-shaped body, with a short clapper or stem which has an opening at its free end. From the edge of the bell or umbrella four pairs of tentacles project. The medusæ usually separate from the parent polyp and live an independent, free-swimming life. These are the beautiful animals commonly known as jelly-fishes. The medusæ or jelly-fishes produce special reproductive

cells, a single medusa producing only one kind of such cells—that is, producing either egg cells alone or sperm cells alone. The active sperm cells produced by one medusa find their way to an egg cell producing medusa, and fuse with or fertilize these egg cells. The

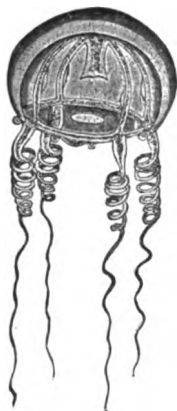


FIG. 20.—A medusa, *Eucopa*.
—After HAECKEL.

fertilized egg develops into a small, oval, free-swimming embryo called a *planula*, which finally attaches itself to a stone or bit of wood or seaweed, and grows to be a simple cylindrical polyp attached at its base and with mouth and tentacles at its free end. This polyp gives rise by budding to new polyps, which remain attached to it, and gradually a new tree-like colony is formed. From this polyp or this colony new medusæ bud off, swim away, and finally produce new polyps. Thus there is in the life of the polyps what is called an *alternation*

of generations. There are two kinds of individuals which evidently belong to the same species of animal, or, put in another way, one kind of animal has two distinct forms. This appearance of one kind of animal in two forms is called *dimorphism*. We shall see later that one kind of animal may appear in more than two forms; such a condition is called *polymorphism*. In alternation of generations we have the polyp animal appearing in one generation as a fixed cylindrical polyp, while in the next generation it is a free-swimming, umbrella-shaped medusa or jelly-fish.

The polyps which are dimorphic—that is, have a polyp form of individual and a medusa form of individual—show more differentiation in structure than the simple *Hydra*. This further differentiation is especially apparent in the medusæ or jelly-fishes. Here the nerve cells are aggregated in little groups arranged along the edge of the umbrella

to form distinct sense organs. The muscle processes are better developed, and the digestive cavity is differentiated into central and peripheral portions. In these dimorphic polyps the fixed polyp individuals reproduce by the simple way of budding, while the medusa individuals reproduce by producing special reproductive cells of two kinds, which must fuse to form a cell capable of developing into a new polyp.

25. **Coral.**—There are many kinds of polyps and jelly-fishes, and they present a great variety of shape and size and general appearance. Many polyps exist only in the true polyp form, never producing medusæ. Others have



FIG. 21.—A polyp, or sea-anemone (*Metridium dianthus*).

only the medusa form. Some live in colonies, and others are always solitary. The animals we know as corals are polyps which live in enormous colonies, and which exist only in the true polyp form, not producing medusæ. They

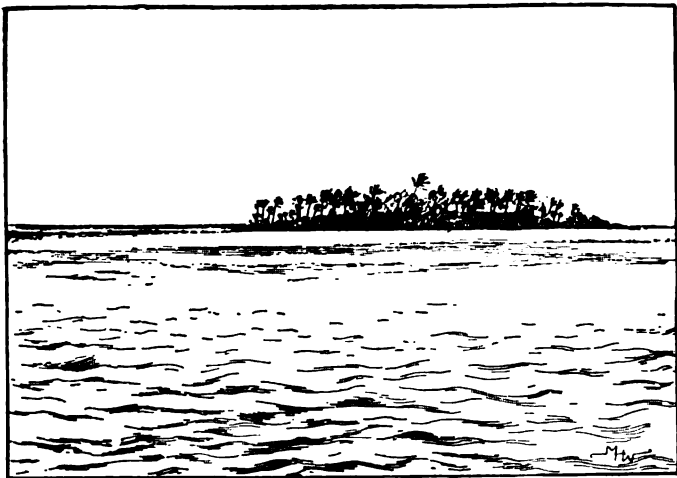


FIG. 22.—Coral island (Nannku Levu, of the Fiji group). (After a photograph by MAX AGASSIZ.)



FIG. 23.—Shore of a coral island, with cocoanut palms. (After a photograph.)

form a firm skeleton of lime (calcium carbonate), and after their death these skeletons persist, and because of their abundance and close massing form great reefs or banks and islands. Coral islands occur only in the warmer oceans. In the Atlantic they are found along the coasts of southern Florida, Brazil, and the West Indies; in the Pacific and Indian Oceans there are great coral reefs on the coast of Australia, Madagascar, and elsewhere, and certain large

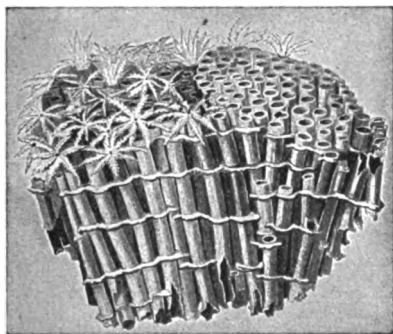


FIG. 24.—Organ-pipe coral.

groups of inhabited islands like the Fiji, Society, and Friendly Islands are composed exclusively of coral islands. More than two thousand kinds of living corals are known, and their skeletons offer much variety in structure and appearance. Brain coral, organ-pipe coral (Fig. 24), the well-known red coral from Italy and Sicily, used as jewelry, and the sea pens and sea fans are among the better known and more beautiful kinds of coral skeletons.

26. Colonial jelly-fishes.—While many of the medusæ or jelly-fishes are another form of individual of a true fixed polyp, many of the larger and more beautiful jelly-fishes do not exist in any other form. Some of these larger jelly-fishes are several feet in diameter, and when cast up on the beach form a great shapeless mass of soft, jelly-like sub-

stance. The bodies of all jelly-fishes are soft and gelatinous, the body substance containing hardly one per cent of solid matter. It is mostly water. Many jelly-fishes are beautifully and strikingly colored, and as they swim slowly about near the surface of the ocean, lazily opening and shutting their iridescent, umbrella-like bodies, they are among the most beautiful of marine organisms. When one of the jelly-fishes is taken from the water, however, it quickly loses its brilliant colors, and dries away to a shapeless, shriveling, sticky mass.

Some of the most beautiful of the jelly-fishes belong to a group called the Siphonophora. These jelly-fishes are elongate and tube-like rather than umbrella- or bell-shaped, and they are polymorphic—that is, there are several different forms of individuals belonging to a single kind or species. The Siphonophora are all free-swimming, but nevertheless form small colonies. In the Mediterranean Sea and in other southern ocean waters the surface may be covered for great areas by these brilliantly colored jelly-fish colonies, each of which looks, as a celebrated German naturalist has said, like a swimming flower cluster whose parts, flowers, stems, and leaves seem to be made of transparent crystal, but which possess the life and soul of an animal. An abundant species of these Siphonophora (Fig. 25) is composed of a slender, flexible, floating, central stem several feet long, to which are attached thousands of medusa and polyp individuals representing several different kinds of forms, each kind of individual being specially modified or adapted to perform some one duty. The central stem is a greatly elongated polyp individual, whose upper end is dilated and filled with air to form a float. This individual holds up the whole colony. Grouped around this central stem just below the float are many bell-shaped bodies which alternately open and close, and by thus drawing in and expelling water from their cavities impel the whole colony through the water. These bell-shaped structures are attached me-

dusa individuals, whose business it is to be the locomotive organs for the colony. These medusæ are without tentacles, and take no food and produce no young. They have given up the power of performing these other life processes, and devote themselves wholly to the business of locomotion. From the lower end of the central stem rises a host of structures, among which several distinct kinds are readily perceived. One kind is composed of a pear-shaped hollow body open at its free end, and bearing a long tentacle which is furnished with numerous groups of stinging cells. These are the polyp individuals whose especial business it is to capture and sting prey and to eat it. These individuals are the food-getters for the colony. Scattered among these stinging, feeding polyps, are numerous smaller individuals with oval, closed body, each bearing a long, slender thread. These threads

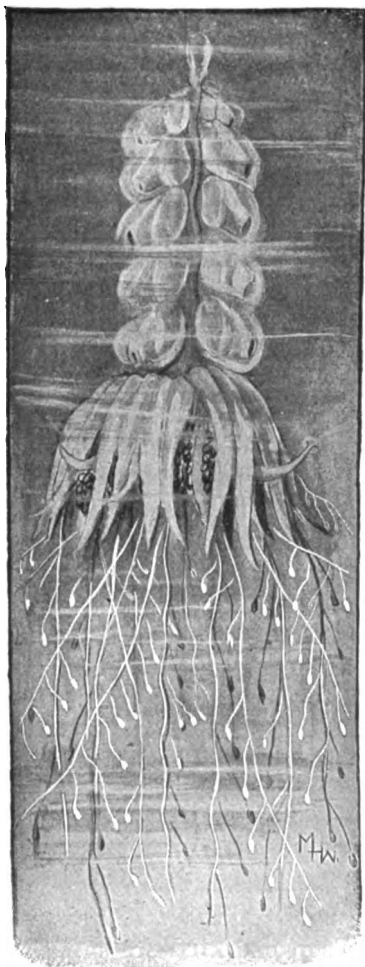


FIG. 25.—A colonial jelly-fish, *Physophora* (after HAECKEL). At the top is the float polyp, around its stem the swimming medusæ, and below are the feeding, feeling, protecting, and reproducing polyps and medusæ.

are very sensitive, and the polyps bearing them have for special function that of feeling or being sensible of stimuli from without. They are the sense organs or sense individuals of the colony. Finally, there are two other kinds of structures or individuals which produce the special reproductive cells for the perpetuation of the species. These are the modified medusa individuals, and one kind, larger than the other, produces the active sperm cells, while the other produces the inactive egg cells.

27. Increase in the degree of complexity.—In the corals, sea-anemones, and jelly-fishes there is plainly much more of a division of labor among the various parts of an individual and much more modification of these parts—that is, much more structural complexity than among the sponges and *Hydra*. And these, in their turn, are more complex than are the colonial Protozoa, the Volvocinæ. There is a great difference in degree of complexity among the slightly complex animals. But the various groups of these animals which we have studied can all be arranged roughly in a series beginning with the least complex among them and ascending to the most complex. And in this series, and in the always accompanying division of labor among the different parts, the gradual increase in complexity is beautifully shown.

From an animal composed of many structurally similar cells, each cell capable of performing all the life processes, we pass to an animal composed of cells of a few different kinds, of slight structural diversity. Each kind of cell devotes itself especially to a certain few life processes or functions. Next we find an animal in which the cells of one kind are specially aggregated to form a single part of the body which is specially devoted to the performance of a single function. This diversity among the cells increases, this aggregation of similar cells to form special parts or organs increases, and the division of labor or assignment of special functions to special organs becomes

more and more pronounced. Among the more complex polyps and jelly-fishes the contractile cells form distinct muscle fibers and muscles; the sensitive cells form distinct nerve cells and nerve fibers which are arranged in a primitive nervous system; the digestive cavity becomes complex and composed of different portions; the reproductive cells are formed by special organs, and the distinction between the egg cells and the sperm cells—that is, between the female reproductive elements and the male reproductive elements—becomes more pronounced.

We have followed this increase or development of structural and physiological complexity from simplest animals to fairly complex ones. The principle of this development of complexity is evident. It will not be profitable to attempt to follow in detail this development among the higher animals. The complex animals are complex because their life processes are performed by special parts of their body, which parts are specially modified so as to perform these processes well. The animals which are more complex than those we have studied differ from these simply in the degree of complexity attained. In order to understand this better we shall not further consider special groups of animals, but special processes or functions, and attempt to see how the modification and increase in complexity of structure goes hand in hand with the increase of elaborateness or complexity in the performance of function. /

CHAPTER III

THE MULTIPLICATION OF ANIMALS AND SEX

28. **All life from life.**—On the performance of the function of reproduction or multiplication depends the existence or perpetuation of the species. Although an animal may take food and perform all the functions necessary to its own life, it does not fulfill the demands of successful existence unless it reproduces itself. Some individuals of every species must produce offspring or the species becomes extinct. We have seen in our study of the simple animals that the function of reproduction is the first function to become differentiated in the ascent from simplest animals to complex animals. The first division of labor among the cells composing the bodies of the slightly complex animals and the first structural differences among the cells are connected with the performance of the function of reproduction or multiplication.

We are all so familiar with the fact that a kitten comes into the world only through being born, as the offspring of parents of its kind, that we shall likely not appreciate at first the full significance of the statement that all life comes from life; that all organisms are produced by other organisms. Nor shall we at first appreciate the importance of the statement. This is a generalization of modern times. It has always been easy to see that cats and horses and chickens and the other animals we familiarly know give birth to young or new animals of their own kind; or, put conversely, that young or new cats and horses and chickens come into existence only as the off-

spring of parents of their kind. And in these latter days of microscopes and mechanical aids to observation it is even easy to see that the smaller animals, the microscopic organisms, come into existence only as they are produced by the division of other similar animals, which we may call their parents. But in the days of the earlier naturalists the life of the microscopic organisms, and even that of many of the larger but unfamiliar animals, was shrouded in mystery. And what seem to us ridiculous beliefs were held regarding the origin of new individuals.

29. **Spontaneous generation.**—The ancients believed that many animals were spontaneously generated. The early naturalists thought that flies arose by spontaneous generation from the decaying matter of dead animals; from a dead horse come myriads of maggots which change into flesh flies. Frogs and many insects were thought to be generated spontaneously from mud. Eels were thought to arise from the slime rubbed from the skin of fishes. Aristotle, the Greek philosopher, who was the greatest of the ancient naturalists, expresses these beliefs in his books. It was not until the middle of the seventeenth century—Aristotle lived three hundred and fifty years before the birth of Christ—that these beliefs were attacked and began to be given up. In the beginning of the seventeenth century William Harvey, an English naturalist, declared that every animal comes from an egg, but he said that the egg might “proceed from parents or arise spontaneously or out of putrefaction.” In the middle of the same century Redi proved that the maggots in decaying meat which produce the flesh flies develop from eggs laid on the meat by flies of the same kind. Other zoölogists of this time were active in investigating the origin of new individuals. And all their discoveries tended to weaken the belief in the theory of spontaneous generation.

Finally, the adherents of this theory were forced to restrict their belief in spontaneous generation to the case

of a few kinds of animals, like parasites and the animalcules of stagnant water. It was maintained that parasites arose spontaneously from the matter of the living animal in which they lay. Many parasites have so complicated and extraordinary a life history that it was only after long and careful study that the truth regarding their origin was discovered. But in the case of every parasite whose life history is known the young are offspring of parents, of other individuals of their kind. No case of spontaneous generation among parasites is known. The same is true of the animalcules of stagnant water. If some water in which there are apparently no living organisms, however minute, be allowed to stand for a few days, it will come to be swarming with microscopic plants and animals. Any organic liquid, as a broth or a vegetable infusion exposed for a short time, becomes foul through the presence of innumerable bacteria, infusoria, and other one-celled animals and plants, or rather through the changes produced by their life processes. But it has been certainly proved that these organisms are not spontaneously produced by the water or organic liquid. A few of them enter the water from the air, in which there are always greater or less numbers of spores of microscopic organisms. These spores (embryo organisms in the resting stage) germinate quickly when they fall into water or some organic liquid, and the rapid succession of generations soon gives rise to the hosts of bacteria and Protozoa which infest all standing water. If all the active organisms and inactive spores in a glass of water are killed by boiling the water, "sterilizing" it, as it is called, and this sterilized water or organic liquid be put into a sterilized glass, and this glass be so well closed that germs or spores can not pass from the air without into the sterilized liquid, no living animals will ever appear in it. It is now known that flesh will not decay or liquids ferment except through the presence of living animals or plants. To sum up, we may say that we know of no instance of the

spontaneous generation of organisms, and that all the animals whose life history we know are produced from other animals of the same kind. "*Omne vivum ex vivo*," All life from life.

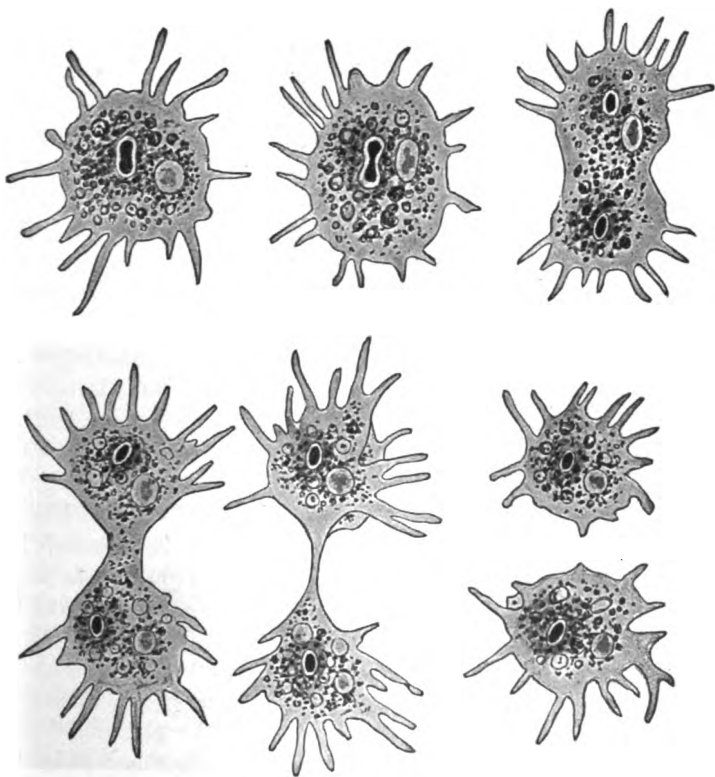


FIG. 26.—The multiplication of *Amaba* by simple fission.

30. The simplest method of multiplication.—In our study of the simplest and the slightly complex animals we became acquainted with the simplest methods of multiplication and with methods which are more complex. The method

of simple fission or splitting—binary fission it is often called, because the division is always in two—by which the body of the parent becomes divided into two equal parts—into halves—is the simplest method of multiplication. This is the usual method of *Amœba* (Fig. 26) and of many other of the simplest animals. In this kind of reproduction it is hardly exact to speak of parent and children. The children, the new *Amœbæ*, are simply the parent cut into halves. The parent persists; it does not produce offspring and die. Its whole body continues to live. The new *Amœbæ* take in and assimilate food and add new matter to the original matter of the parent body; then each of them divides in two. The grandparent's body is now divided into four parts, one fourth of it forming one half of each of the bodies of the four grandchildren. The process of assimilation, growth, and subsequent division takes place again, and again, and again. Each time there is given to the new *Amœba* an ever-lessening part of the actual body substance of the original ancestor. Thus an *Amœba* never dies a natural death, or, as has been said, "no *Amœba* ever lost an ancestor by death." It may be killed outright, but in that case it leaves no descendants. If it is not killed before it produces new *Amœbæ* it never dies, although it ceases to exist as a single individual. The *Amœba* and other simple animals which multiply by direct binary fission may be said to be immortal, and the "immortality of the *Protozoa*" is a phrase which you will be sure to meet if you begin to read the writings of the modern philosophical zoologists.

31. Slightly complex methods of multiplication.—Most of the *Protozoa* multiply or reproduce themselves in two ways—by simple fission and by conjugation. *Paramœcium*, for example, reproduces itself for many generations by fission, but a generation finally appears in which a different method of reproduction is followed. Two individuals come together and each exchanges with the other a part

of its nucleus. Then the two individuals separate and each divides into two. The result of this conjugation is to give to the new *Paramœcia* produced by the conjugating individuals a body which contains part of the body substance of two distinct individuals. The new *Paramœcia* are not simply halves of a single parent; they are parts of two parents. If the two conjugating individuals differ at all—and they always do differ, because no two individual animals, although belonging to the same species, are exactly alike—the new individual, made up of parts of each of them, will differ from both. We shall, as we study further, see that Nature seems intent on making every new individual differ slightly from the individual which produces it; and the method of multiplication or the production of new individuals which Nature has adopted to produce the result is the method which we have seen exhibited in its simplest form among the simplest animals—the method of having two individuals take part in the production of a new one. The further study of multiplication among animals is the study of the development and elaboration of this method.

32. Differentiation of the reproductive cells.—Among the colonial Protozoa the first differentiation of the cells or members composing the colony is the differentiation into two kinds of reproductive cells. Reproduction by simple division, without preceding conjugation, can and does take place, to a certain extent, among all the colonial Protozoa. Indeed, this simple method of multiplication, or some modification of it, like budding, persists among many of the complex animals, as the sponges, the polyps, and even higher and more complex forms. But such a method of single-parent reproduction can not be used alone by a species for many generations, and those animals which possess the power of multiplication in this way always exhibit also the other more complex kind of multiplication, the method of double-parent reproduction. Conjugation takes place between different members of a single colony of one of the

colonial Protozoa, or between members of different colonies of the same species. These conjugating individuals in the simpler kinds of colonies, like *Gonium*, are similar; in *Pandorina* they appear to be slightly different, and in *Eudorina* and *Volvox* the conjugating cells are very different from each other (Figs. 15 and 16). One kind of cell, which is called the egg cell, is large, spherical, and inactive, while the other kind, the sperm cell, is small, with ovoid head and tapering tail, and free-swimming. In the simpler colonial Protozoa all the cells of the body take part in reproduction, but in *Volvox* only certain cells perform this function, and the other cells of the body die. Or we may say that the body of *Volvox* dies after it has produced special reproductive cells which shall fulfill the function of multiplication.

Beginning with the more complex Volvocinæ, which we may call either the most complex of the one-celled animals or the simplest of the many-celled animals, all the complex animals show this distinct differentiation between the reproductive cells and the cells of the rest of the body. Of course, we find, as soon as we go up at all far in the scale of the animal world, that there is a great deal of differentiation among the cells of the body: the cells which have to do with the assimilation of food are of one kind; those on which depend the motions of the body are of another kind; those which take oxygen and those which excrete waste matter are of other kinds. But the first of this cell differentiation, as we have already often repeated, is that shown by the reproductive cells; and with the very first of this differentiation between reproductive cells and the other body cells appears a differentiation of the reproductive cells into two kinds. These two kinds, among all animals, are always essentially similar to the two kinds shown by *Volvox* and the simplest of the many-celled animals—namely, large, inactive, spherical egg cells, and small, active, elongate or “tailed” sperm cells.

33. Sex, or male and female.—In the slightly complex animals one individual produces both egg cells and sperm cells. But in the Siphonophora, or colonial jelly-fishes, studied in the last chapter, certain members of the colony produce only sperm cells, and certain other members of the colony produce only egg cells. If the Siphonophora be considered an individual organism and not a colony composed of many individuals, then, of course, it is like the others of the slightly complex animals in this respect. But as soon as we rise higher in the scale of animal life, as soon as we study the more complex animals, we find that the egg cells and sperm cells are almost always produced by different individuals. Those individuals which produce egg cells are called female, and those which produce sperm cells are called male. There are two sexes. Male and female are terms usually applied only to individuals, but it is evidently fair to call the egg cells the female reproductive cells, and the sperm cells the male reproductive cells. A single individual of the simpler kinds of animals produces both male and female cells. But such an individual can not be said to be either male or female; it is sexless—that is, sex is something which appears only after a certain degree of structural and physiological differentiation is reached. It is true that even among many of the higher or complex animals certain species are not represented by male and female individuals, any individual of the species being able to produce both male and female cells. But this is the exception.

34. The object of sex.—Among almost all the complex animals it is necessary that there be a conjugation of male and female reproductive cells in order that a new individual may be produced. This necessity first appears, we remember, among very simple animals. This intermixing of body substance from two distinct individuals, and the development therefrom of the new individual, is a phenomenon which takes place through the whole scale of animal life.

The object of this intermixing is the production of variation. Nature demands that the offspring shall differ slightly from its parents. By having the beginnings of its body, the single cell from which the whole body develops, composed of parts of two different individuals, this difference, although slight and nearly imperceptible, is insured. Sex is a provision of Nature which insures variation.

35. **Sex dimorphism.**—As we have seen, almost every species of animal is represented by two kinds of individuals, males and females. In the case of many animals, espe-

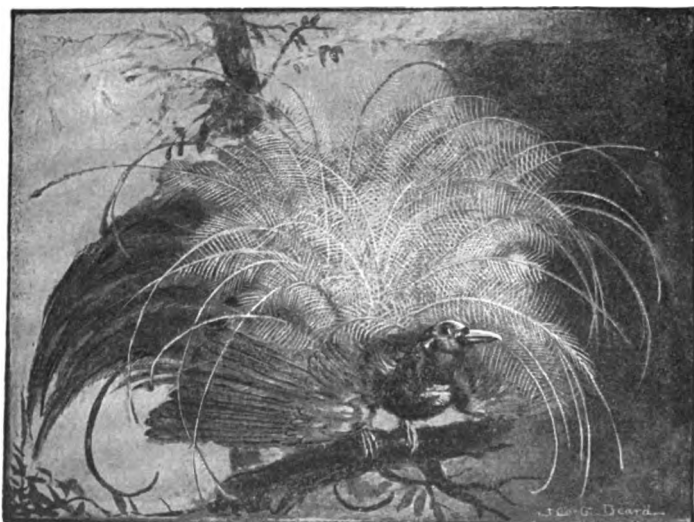


FIG. 27.—Bird of paradise, male.

cially the simpler ones, these two kinds of individuals do not differ in appearance or in structure apart from the organs concerned with multiplication. But with many animals the sexes can be readily distinguished. The male and female individuals often show marked differences, especially in external structural characters. We can read-

ily tell the peacock, with its splendidly ornamental tail feathers, from the unadorned peafowl, or the horned ram from the bleating ewe. There is here, plainly, a dimorphism—the existence of two kinds of individuals belonging to a single species. This dimorphism is due to sex, and the condition may be called sex dimorphism. Among some animals this sex dimorphism, or difference between the sexes, is carried to extraordinary extremes. This is especially true among polygamous animals, or those in which the males mate with many females, and are forced to fight for their possession. The male bird of paradise, with its gorgeous display of brilliantly colored and fantastically shaped feathers (Fig. 27), seems a wholly different kind of bird from the modest brown female. The male golden and silver pheasants, and allied species with their elaborate plumage, are very unlike the dull-colored females. The great, rough, warlike male fur seal, roaring like a lion, is three times as large as the dainty, soft-furred female, which bleats like a sheep.

Among some of the lower animals the differences between male and female are even greater. The males of the common cankerworm moth (Fig. 28) have four wings;



FIG. 28.—Cankerworm moth; the winged male and wingless female.

the females are wingless, and several other insect species show this same difference. Among certain species of white ants the females grow to be five or six inches long, while the males do not exceed half an inch in length. In the

case of some of the parasitic worms which live in the bodies of other animals, the male has an extraordinarily degraded, simple body, much smaller than that of the female and differing greatly from that of the female in structure.

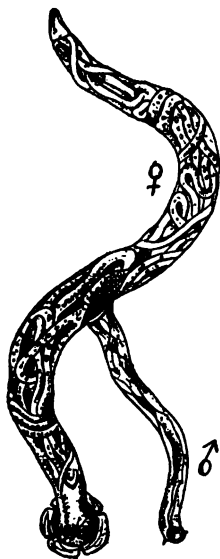


FIG. 29.—The parasitic worm (*Syngamus trachealis*), which causes the "gapes" in fowls. The male is attached to the female, and lives as a parasite on her.

In some cases even—as, for example, the worm which causes "gapes" in chickens—the male lives parasitically on the female, being attached to the body of the female for its whole lifetime, and drawing its nourishment from her blood (Fig. 29).

A condition known as *parthenogenesis* is found among certain of the complex animals. Although the species is represented by individuals of both sexes, the female can produce young from eggs which have not been fertilized. For example, the queen bee lays both fertilized and unfertilized eggs. From the fertilized eggs hatch the workers, which are rudimentary females, and other queens, which are fully-developed females; from the unfertilized eggs hatch only males—the drones. Many generations of plant lice are produced each year parthenogenetically—that is, by unfertilized females.

But there is at least one generation each year produced in the normal way from fertilized eggs.

Some of the complex animals are *hermaphroditic*—that is, a single individual produces both egg cells and sperm cells. The tapeworm and many allied worms show this condition. This is the normal condition for the simplest animals, as we have already learned, but it is an exceptional condition among the complex animals.

36. The number of young.—There is great variation in the number of young produced by different species of animals. Among the animals we know familiarly, as the mammals, which give birth to young alive, and the birds, which lay eggs, it is the general rule that but few young are produced at a time, and the young are born or eggs are laid only once or perhaps a few times in a year. The robin lays five or six eggs once or twice a year; a cow may produce a calf each year. Rabbits and pigeons are more prolific, each having several broods a year. But when we observe the multiplication of some of the animals whose habits are not so familiar to us, we find that the production of so few young is the exceptional and not the usual habit. A lobster lays ten thousand eggs at a time; a queen bee lays about five million eggs in her life of four or five years. A female white ant, which after it is full grown does nothing but lie in a cell and lay eggs, produces eighty thousand eggs a day steadily for several months. A large codfish was found on dissection to contain about eight million eggs.

If we search for some reason for this great difference in fertility among different animals, we may find a promising clew by attending to the duration of life of animals, and to the amount of care for the young exercised by the parents. We find it to be the general rule that animals which live many years, and which take care of their young, produce but few young; while animals which live but a short time, and which do not care for their young, are very prolific. The codfish produces its millions of eggs; thousands are eaten by sculpins and other predatory fishes before they are hatched, and other thousands of the defenseless young fish are eaten long before attaining maturity. Of the great number produced by the parent, a few only reach maturity and produce new young. But the eggs of the robin are hatched and protected, and the helpless fledglings are fed and cared for until able to cope with their natural

enemies. In the next year another brood is carefully reared, and so on for the few years of the robin's life.

Under normal conditions in any given locality the number of individuals of a certain species of animal remains about the same. The fish which produces tens of thousands of eggs and the bird which reproduces half a dozen eggs a year maintain equally well their numbers. In one case a few survive of many born ; in the other many (relatively) survive of the few born ; in both cases the species is effectively maintained. In general, no agency for the perpetuation of the species is so effective as that of care for the young.

CHAPTER IV

FUNCTION AND STRUCTURE

37. **Organs and functions.**—An animal does certain things which are necessary to life. It eats and digests food, it breathes in air and takes oxygen from it and breathes out carbonic-acid gas; it feels and has other sensations; it produces offspring, thus reproducing itself. These things are done by the simplest animals as well as by the complex animals. But while with the simplest animals the whole body (which is but a single cell) takes part in doing each of these things, among the complex animals only a part of the body is concerned with any one of these things. Only a part of the body has to do with the taking in of oxygen. Another part has to do with the digestion of food, and another with the business of locomotion. These parts of the body, as we know, differ from each other, and they differ because they have different things to do. These different parts are called *organs* of the body, and the things they do are called their *functions*. The nostrils, tracheæ, and lungs are the organs which have for function the process of respiration. The legs of a cat are the organs which perform for it the function of locomotion. The structure of one of the higher animals is complex because the body is made up of many distinct organs having distinct functions. The things done by one of the complex animals are many; around each of the principal functions or necessary processes, as a center, are grouped many minor accessory functions, all helping to make more successful the accom-

plishment of the principal functions. While many of the lower animals have no eyes and no ears, and trust to more primitive means to discover food or avoid enemies, the higher animals have extraordinarily complex organs for seeing and hearing, two functions which are accessory only to such a principal function as food-taking.

38. Differentiation of structure.—We have seen, in our study of the slightly complex animals, how the body becomes more and more complex in proportion to the degree in which the different life processes are divided or assigned to different parts of it for performance. With the gradually increasing division of labor the body becomes less homogeneous in structure; a differentiation of structure becomes apparent and gradually increases. The extent of the division of labor and the extent of the differentiation of structure, or division of the body into distinct and different parts and organs, go hand in hand. An animal in which the division of labor is carried to an extreme is an animal in which complexity of structure is extreme.

39. Anatomy and physiology.—Zoölogy, or the study of animals, is divided for convenience into several branches or phases. The study of the classification of animals is called systematic zoölogy; the study of the development of animals from their beginning as a single cell to the time of their birth is called animal embryology; the study of the structure of animals is called animal anatomy, and the study of the performance of their life processes or functions is called physiology. Because the whole field of zoölogy is so great, some zoölogists limit themselves exclusively to one of these phases of zoölogical study, and those who do not so definitely limit their study, at least give their special attention to a single phase, although all try to keep in touch with the state of knowledge in other phases. In earlier days the study of the anatomy of animals and of their physiology were held to be two very distinct lines of investigation, and the anatomists paid little attention to

physiology and the physiologists little to anatomy. But we have seen how inseparably linked are structure and function. The structure of an animal is as it is because of the work it has to do, and the functions of an animal are performed as they are performed because of the special structural condition of the organs which perform them. The study of the anatomy and the study of the physiology of animals can not be separated. To understand aright the structure of an animal it is necessary to know to what use the structure is put; to understand aright the processes of an animal it is necessary to know the structure on which the performance of the processes depends.

40. **The animal body a machine.**—The body of an animal may be well compared with some machine like a locomotive engine. Indeed, the animal body is a machine. It is a machine composed of many parts, each part doing some particular kind of work for which a particular kind of structure fits it; and all the parts are dependent on each other and work together for the accomplishment of the total business of the machine. The locomotive must be provided with fuel, such as coal or wood or other readily combustible substance, the consumption of which furnishes the force or energy of the machine. The animal body must be provided with fuel, which is called food, which furnishes similarly the energy of the animal. Oxygen must be provided for the combustion of the fuel in the locomotive and the food in the body. The locomotive is composed of special parts: the firebox for the reception and combustion of fuel; the steam pipes for the carriage of steam; the wheels for locomotion; the smoke stack for throwing off of waste. The animal body is similarly composed of parts: the alimentary canal for the reception and assimilation of food; the excretory organs for the throwing off of waste matter; the arteries and veins for the carriage of the oxygen and food-holding blood; the legs or wings for locomotion.

The locomotive is an inorganic machine ; the animal is an organic machine. There is a great and real difference between an organism, a living animal, and a locomotive, an inorganic structure. But for a good understanding of the relation between function and structure, and of the composition of the body of the complex animals, the comparison of the animal and locomotive is very instructive.

41. The specialization of organs.—The organ for the performance of some definite function in one of the higher animals may be very complex. The corresponding organ in one of the lower animals for the performance of the same function may be comparatively simple. For example, the organ for the digestion of food is, in the case of the polyp, a simple cylindrical cavity in the body into which food enters through a large opening at the apical or free end of the body. The digestive organ of a cow is a long coiled tube, comprising many regions of distinct structural and physiological character and altogether extremely complicated. An organ in simple or primitive condition is said to be *generalized* ; in complex or highly modified condition it is said to be *specialized*. That is, an organ may be modified and complexly developed to perform its function in a special way, in a way differing in many particulars from the way the corresponding organ in some other animal performs the same general function. The specialization of organs, or their modification to perform their functions in special ways, is what makes animal bodies complex, for specialization is almost always in the line of complexity. Later we shall see more clearly how specialization is brought about. For the present we may study one of the more important organs of the animal body for the sake of having concrete examples of some of the general statements made in this discussion of function and structure.

42. The alimentary canal.—The organ which has to do with the taking and digesting of food is called the ali-

mentary canal. In some of the higher animals this is a very complex organ. In the cow, one of the cud-chewing mammals or ruminants, it consists of several distinct portions, which differ among themselves very much (Fig. 30). First, there is the mouth, or opening for the entrance of the food. The mouth is supplied with teeth for tearing off and chewing the food, with a tongue for manipulating it, and with taste papillæ situated on the tongue and palate for determining the desirability of the food. Into the mouth a peculiar fluid (the saliva) is poured by certain glands, organs accessory to the alimentary canal. The herbage bitten off, mixed with saliva, and rolled by the tongue into a ball, passes back through a narrow tube, the œsophagus, and into a sac called the rumen, or paunch. Here it lies until the cow ceases for the while to take in food, when it passes back again through the œsophagus and into the mouth for mastication. After being masticated it again passes downward through the œsophagus, and enters this time another sac called the reticulum, lying next to the rumen. From here it passes into another sac-like portion of the alimentary canal called the omasum, where it is strained through numerous leaf-like folds which line the walls of this part of the canal. From here the food passes into a fourth

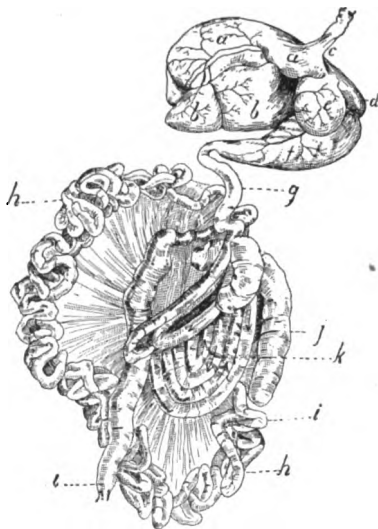


FIG. 30.—Alimentary canal of the ox (after COLIN and MÜLLER). *a*, rumen (left hemisphere); *b*, rumen (right hemisphere); *c*, insertion of œsophagus; *d*, reticulum; *e*, omasum; *f*, abomasum; *g*, duodenum; *h* and *i*, jejunum and ileum; *j*, cæcum; *k*, colon, with its various convolutions; *l*, rectum.

sac-like part of the canal, called the abomasum. Here the process of digestion goes on. The four sacs—rumen, reticulum, omasum, and abomasum—are called stomachs, or they may be considered to be four chambers forming one large stomach. In the abomasum, or digesting stomach, digestive fluids are poured from glands lining its walls, and the food becomes converted into a liquid called chyle. The chyle passes from the stomach into a long, narrow, tubular portion of the canal called the intestine. The intestine is very long, and lies coiled in a large mass in the body of the cow. The intestine is divided into distinct regions, which vary in size and in the character of the inner wall. These parts of the intestine have names, as duodenum, jejunum, ileum, cæcum, colon, etc. Part of the intestine is lined inside with fine papillæ, which take up the chyle (the digested food) and pass it through the walls of the intestine to other special organs, which pass it on to the blood, with which it becomes mixed and carried by an elaborate system of tubes to all parts of the body. Part of the grass taken into the alimentary canal by the cow can not be digested, and must be got rid of. This passes on into a final posterior part of the intestine called the rectum, and leaves the body through the anus or posterior opening of the alimentary canal. The whole canal is more than twenty times as long as the body of the cow; it is composed of parts of different shape; its walls are supplied with muscles and blood-vessels; the inner lining is covered with folds, papillæ, and gland cells. It is altogether a highly specialized organ, a structurally complex and elaborately functioning organ.

Let us now examine the alimentary canal, or organ of digestion, in some of the simpler animals.

The Protozoa, or simplest animals, have no special organ at all. When the surface of the body of an *Amoeba* comes into contact with an organic particle which will serve as food, the surface becomes bent in at the point of its con-

tact with the food particle, and the body substance simply incloses the food (Fig. 3). Food is taken in by the surface. The whole outer surface of the body is the food-taking organ. In the simplest many-celled animals, the sponges, there is no special food-taking and digestive organ. Each of the cells of the body takes in and assimilates food for itself. The sponge is like a great group of *Amœbæ* holding fast to each other, but each looking out for its own necessities. Among the polyps, however, there is a definite organ of digestion—that is, food is only taken and digested by certain parts of the body. The simple polyp's body (Fig. 31) is a cylinder or vase closed at one end and open at the other end, and attached by the closed end to a rock. The opening is usually of less diameter than the diameter of the body, and it is surrounded by a number of tentacles, whose

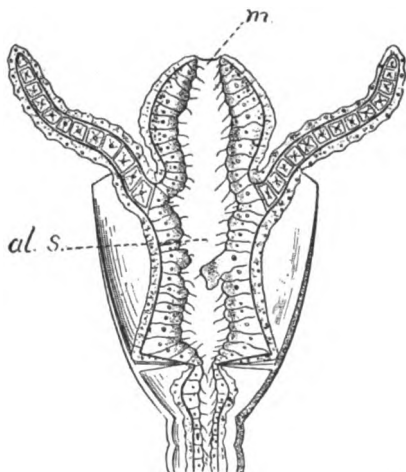


FIG. 31.—*Obelia* sp., a simple polyp; vertical section, highly magnified. *m.*, mouth opening; *al. s.*, alimentary sac.—After PARKER and HASWELL.

function it is to seize the food and convey it to the mouth opening. There are, of course, no teeth, no tongue, none of the various parts which are in or are part of the mouth of the higher animals. The polyp's mouth is simply a hole or opening into the inside of the body. This body cavity, or simplest of all stomachs, is simply the cylindrical or vase-shaped hollow space inclosed by the body wall. This space extends also into the tentacles. There is no other opening, no posterior or anal opening. We can not

speak of an œsophagus or intestine in connection with this most primitive of alimentary sacs. The cells which line the sacs show some differentiation; some are gland cells and secrete digestive fluids; some are amœboid and are provided with pseudopods or flagella for seizing bits of food. The food caught by the tentacles comes into the alimentary sac through the opening or primitive mouth, and

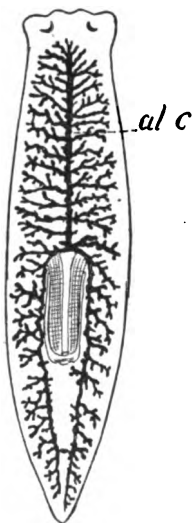


FIG. 32.—Diagrammatic sketch of a flatworm (*Planaria*), showing the branched alimentary canal, *al. c.*—After JIJIMA and HATSCHKE.

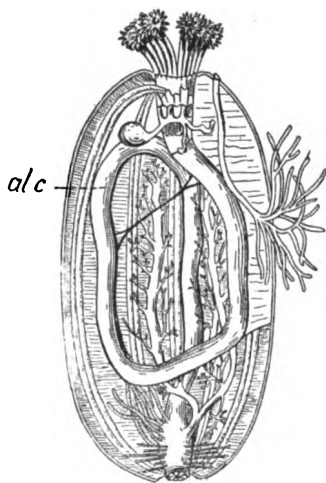


FIG. 33.—Sea-cucumber (*Holothurian*) dissected to show alimentary canal, *al. c.*—After LEUCKART.

what of it is digestible is, by the aid of the gland cells and the amœboid cells, taken up and assimilated, while the rest of it is carried out by water currents again through the single opening.

In the flatworms (Fig. 32) like *Planaria* (small, thin, flattened worms to be found in the mud at the bottom of fresh-water ponds) the mouth opens into a short, narrow tube which may be called an œsophagus. The œsophagus

connects the mouth with the rest of the alimentary canal, which gives out many side branches or diverticula, which are themselves branched, so that the alimentary sac or stomach is a system of ramifying tubes extending from a central main tube to all parts of the body of the worm. There is no anal opening. In the round or thread worms, of which the deadly *Trichina* is an example, the alimentary canal is a simple straight tube with both anterior or mouth opening and posterior or anal opening. In the sea-urchins and sea-cucumbers (Fig. 33) the alimentary canal is a simple tube with two openings, but it is longer than the body between mouth and anus, and so is more or less bent or coiled. In the earthworm the alimentary canal (Fig. 34), although a simple straight tube running through the body, plainly shows a differentiation into particular regions. Behind the mouth opening the alimentary tube is large and thick-walled and is called the pharynx; behind the pharynx it is narrower and is called the œsophagus. Behind the œsophagus it expands to form a rounded, thin-walled chamber called the crop, and just behind this there is another rounded but very thick-walled chamber called the gizzard. From the gizzard back the alimentary canal is about uniform in size, being rather wide and having thick, soft walls. This portion of it is called the intestine. The

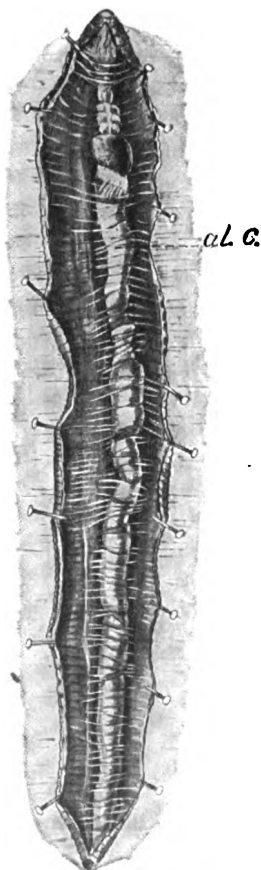


FIG. 34.—Earthworm dissected to show alimentary canal, *al. c.*

posterior part of the intestine, called the rectum, leads to the anal opening. There is some differentiation of the inner surface of the canal. In the great group of mollusks, of which the common fresh-water clam or mussel is an example, the alimentary canal (Fig. 35) shows much variation. The microscopic plants, which are the food of the mussel, are taken in through the mouth and pass into a short œsophagus, thence into a wide stomach and there digested. Behind the stomach is a long, much-folded, narrow intestine which winds about through the fleshy "foot" and finally reaches the surface of the body, and has an anal opening at a point opposite the position of the mouth.

Among the insects there is a great range in degree of complexity of the alimentary canal. The digestive organs are, however, in most insects in a condition of high specialization. The mouth opening is provided with well-developed

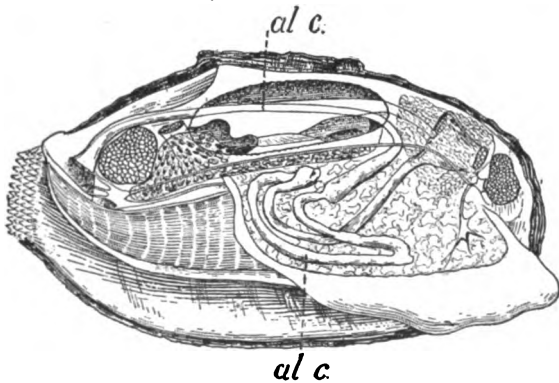


FIG. 35.—Pond mussel dissected to show alimentary canal, *al. c.*—After HATSCHKE and CORI.

biting and masticating or piercing and sucking mouth parts; pharynx, œsophagus, stomach, and intestine are always differentiated and sometimes greatly modified. In the common cockroach, for example (Fig. 36), the mouth has a complicated food-getting apparatus, and the canal, which

is much longer than the body of the insect, and hence much bent and coiled, consists of a pharynx, œsophagus, fore-stomach or proventriculus, true digesting stomach or ventriculus, intestine, and rectum which opens at the posterior tip of the body. The inner lining of the canal shows much differentiation in the different parts of the canal, and there are numerous accessory glands connected with various parts of the canal.

Finally, among the highest animals, the vertebrates, we find still more elaborate specialization of the alimentary canal. As an example the alimentary canal of a cow has already been described in detail.

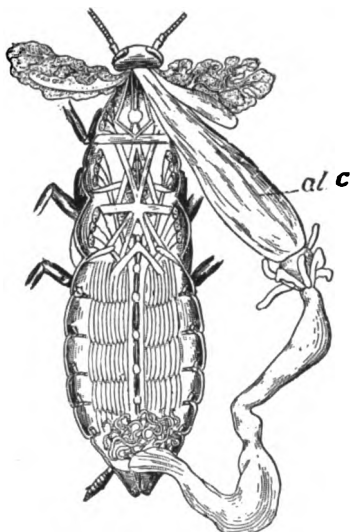


FIG. 36.—Cockroach dissected to show alimentary canal, *al. c.*—After HATSCHEK and CORI.

43. Stable and variable characteristics of an organ.—In spite of all this variation in the structure and general character of the alimentary canal, there are certain characteristics which are features of all alimentary canals. In the examination of an organ we must ever distinguish between its so-called constant or stable characteristics and its inconstant or variable characteristics. The constant characteristics are the fundamentally essential ones of the organ; the variable ones are the special characteristics which adapt the organ for the peculiar habits of the animal possessing it—habits which may differ very much from those of some other animal of similar size, similar distribution, similar abundance.

44. Stable and variable characteristics of the alimentary canal.—A tiger or a lion has an alimentary canal not more

than three or four times the length of its body, while a sheep has an alimentary canal twenty-eight times as long as its body. The tiger is carnivorous; the sheep herbivorous. Associated with the different food habits of the two animals is a striking difference in the alimentary canals. Animals like the horse or cat, which chew their food before swallowing it, have a slender œsophagus; animals like snakes which swallow their food whole have a wide œsophagus. Birds, that have no teeth and hence can not masticate or grind their food in their mouths, usually have a special grinding stomach, the gizzard, for this purpose. And so we might cite innumerable examples of these inconstant or variable characteristics of the alimentary canal. On the other hand, the alimentary canals of all the many-celled animals except the lowest agree in certain important characteristics. Each alimentary canal has two openings, one for the ingress of food and one for the exit of the indigestible portions of the matter taken in, and the canal itself stretches through the body from mouth to anus as a tube, now narrow, now wide, now suddenly expanding into a sac or giving off lateral diverticula, but always simply a lumen or hollow inclosed by a flexible muscular wall. The inner lining of the wall is provided with secreting and absorbing structures. Indeed, we can reduce the essential characters of the alimentary canal to even more simple features. The organ of digestion or assimilation of all the many-celled animals is merely a surface with which food is brought into contact, and which has the power of digesting this food by means of digestive secretions, and of absorbing the food when digested. This surface is small or great in extent, depending upon the amount of food necessary to the life of the animal and the difficulty or readiness with which the food can be digested. This surface might just as well be on the outside of the animal's body as on the inside, if it were convenient. In fact, it is on the outside of some animals. Among the Protozoa the

digesting surface is simply the external surface of the body. And not alone among the one-celled animals. Many of the parasitic worms which live in the bodies of other animals, and the larvæ or "grubs" of many insects which lie in the tissues of plants bathed by the sap, have no inner alimentary canal, but take food through the outer surface of the body. But in these cases the food is ready for immediate absorption, so that no special treatment of it is necessary; hence no complex structures are required.

Even were no such special treatment of the food necessary in the case of the larger animals, it would still be im-

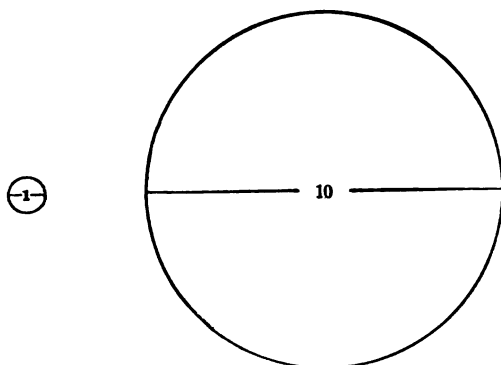


FIG. 37.—Diagram illustrating increase of volume and surface with increase of diameter of sphere.

possible for the simple external surface of the body to serve for food absorption, because of the well-known relation between the surface and the mass of a solid body. When a solid body in the form of a sphere increases in size, its mass or volume increases as the cube of the diameter, while the surface increases only as the square of the diameter (Fig. 37). The external surface of minute animals a few millimeters in diameter can take up enough food to supply the whole body mass. But among large animals this food-getting surface is increased as the square of the diameter of

the body, while the volume or food-using surface of the body is increased as the cube of its diameter. The food supplying can not keep pace with the food using. Hence it is absolutely essential that among large animals the food-taking surface be increased so that it will remain in the same favorable proportion to the mass of the animal as is the case among the minute animals, where the simple external body surface is sufficient to obtain all the food necessary. This increase of surface, without an accompanying increase of size of the animal, is accomplished by having the digesting and assimilating surface inside the body and by having it greatly folded. The surface of the alimentary canal is, after all, simply a bent-in continuation of the outer surface of the body. It is open to the outside of the body by two openings, and wholly closed (except by its porosity) to the true inside of the body. By the bending and coiling of the alimentary canal, and by the repeated folding of its inner wall, the alimentary surface is greatly increased. The necessity for this increase accounts largely for the complexity of the alimentary canal.

But it is not alone this necessity for increased surface that accounts for the great specialization of the alimentary canal in such animals as the insects and the vertebrates. The structural differences in different portions of the canal, resulting in the differentiation of the canal into distinct parts, or the differentiation of the whole organ into distinct subordinate organs, each with a special work or function to perform, are the result of the necessity for the special manipulation of the special kinds of foods taken. Animals which feed on other animals must have mouth structures fit for seizing and rending their prey, and the alimentary canal must be specially modified for the digestion of flesh. Animals which feed on vegetable substances must have special modifications of the alimentary canal quite different from those of the carnivores. Some insects, like the mosquito, take only liquid food, the sap of plants, or the blood

of animals ; others, like the weevils, feed on the hard, dry substance of seeds and grains ; others, like the grasshoppers and caterpillars, eat green leaves ; and still others eat other insects. The alimentary canal of each of these kinds of insects differs more or less from that of the other kinds. The specialization of the alimentary canal depends then upon the necessity for a large food-digesting and absorbing surface, and on the complex treatment of the food. The character of this specialization in each case depends upon the special kind or quality of food taken by the animal in question.

45. **The mutual relation of function and structure.**—The structure of an animal depends upon the manner in which the life processes or functions of the animal are performed. If the functions are performed in a complex manner, the structure of the body is complex ; if the functions are performed in simple manner, the body will be simple in structure. With the increase in degree of the division of labor among various parts of the body, there is an increase in definiteness and extent of differentiation of structure. Each part or organ of the body becomes more modified and better fitted to perform its own special function. A peculiar structural condition of any part of the body, or of the whole body of any animal, is not to be looked on as a freak of Nature, or as a wonder or marvel. Such a structure has a significance which may be sought for. The unusual structural condition is associated with some special habit or manner of performance of a function. Function and structure are always associated in Nature, and should always be associated in our study of Nature.

CHAPTER V

THE LIFE CYCLE

46. Birth, growth and development, and death.—Certain phenomena are familiar to us as occurring inevitably in the life of every animal. Each individual is born in an immature or young condition ; it grows (that is, it increases in size), and develops (that is, changes more or less in structure), and dies. These phenomena occur in the succession of birth, growth and development, and death. But before any animal appears to us as an independent individual—that is, outside the body of the mother and outside of an egg (i. e., before birth or hatching, as we are accustomed to call such appearance)—it has already undergone a longer or shorter period of life. It has been a new living organism hours or days or months, perhaps, before its appearance to us. This period of life has been passed inside an egg, or as an egg or in the egg stage, as it is variously termed. The life of an animal as a distinct organism begins in an egg. And the true life cycle of an organism is its life from egg through birth, growth and development, and maturity to the time it produces new organisms in the condition of eggs. The life cycle is from egg to egg. Birth and growth, two of the phenomena readily apparent to us in the life of every animal, are two phenomena in the true life cycle. Death is a third inevitable phenomenon in the life of each individual, but it is not a part of the cycle. It is something outside.

47. Life cycle of simplest animals.—The simplest animals have no true egg stage, nor perhaps have they any true

death. The new *Amœbæ* are from their beginning like the full-grown *Amœba*, except as regards size. And the old *Amœba* does not die, because its whole body continues to live, although in two parts—the two new *Amœbæ*. The life cycle of the simplest animals includes birth (usually by simple fission of the body of the parent), growth, and some, but usually very little, development, and finally the reproduction of new individuals, not by the formation of eggs, but by direct division of the body.

48. **The egg.**—In our study of the multiplication of animals (Chapter III) we learned that it is the almost univer-

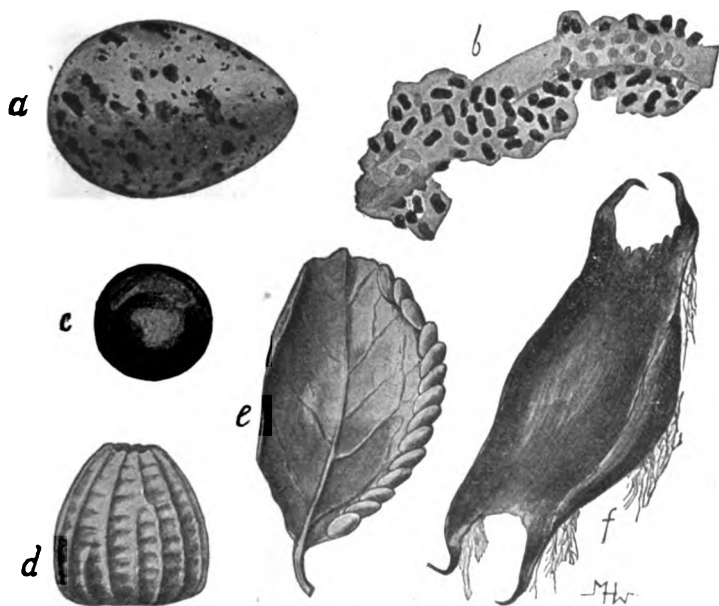


FIG. 38.—Eggs of different animals showing variety in external appearance. *a*, egg of bird; *b*, eggs of toad; *c*, egg of fish; *d*, egg of butterfly; *e*, eggs of katydid on leaf; *f*, egg-case of skate.

sal rule among many-celled animals that each individual begins life as a single cell, which has been produced by the

fusion of two germ cells, a sperm cell from a male individual of the species and an egg cell from a female individual of the species. The single cell thus formed is called the fertilized egg cell, and its subsequent development results in the formation of a new individual of the same species with its parents. Now, in the development of this cell into a new animal, food is necessary, and sometimes a certain amount of warmth. So with the fertilized egg cell there is, in the case of all animals that lay eggs, a greater or less amount of food matter—food yolk, it is called—gathered about the germ cell, and both germ cell and food yolk are inclosed in a soft or hard wall. Thus is composed the egg as we know it. The hen's egg is as large as it is because of the great amount of food yolk it contains. The egg of a fish as large as a hen is much smaller than the hen's egg; it contains less food yolk. Eggs (Fig. 38) may vary also in their external appearance, because of the different kinds of membrane or shells which may inclose and protect them. Thus the frog's eggs are inclosed in a thin membrane and imbedded in a soft, jelly-like substance; the skate's egg has a tough, dark-brown leathery inclosing wall; the spiral egg of the bull-head sharks is leathery and colored like the dark-olive seaweeds among which it lies; and a bird's egg has a hard shell of carbonate of lime. But in each case there is the essential fertilized germ cell; in this the eggs of hen and fish and butterfly and cray-fish and worm are alike, however much they may differ in size and external appearance.

49. Embryonic and post-embryonic development.—Some animals do not lay eggs, that is they do not deposit the fertilized egg cell outside of the body, but allow the development of the new individual to go on inside the body of the mother for a longer or shorter period. The mammals and some other animals have this habit. When such an animal issues from the body of the mother, it is said to be born. When the developing animal issues from an egg

which has been deposited outside the body of the mother, it is said to hatch. The animal at birth or at time of hatching is not yet fully developed. Only part of its development or period of immaturity is passed within the egg or within the body of the mother. That part of its life thus passed within the egg or mother's body is called the embryonic life or embryonic stages of development; while that period of development or immaturity from the time of birth or hatching until maturity is reached is called the post-embryonic life or post-embryonic stages of development.

50. **First stages in development.**—The embryonic development is from the beginning up to a certain point practically identical for all many-celled animals—that is, there are cer-

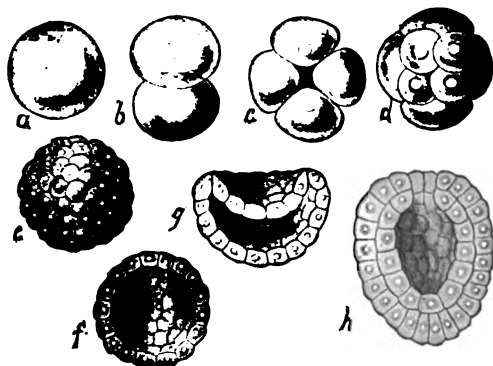


FIG. 39.—First stages in embryonic development of the pond snail (*Lymnaea*). *a*, egg cell; *b*, first cleavage; *c*, second cleavage; *d*, third cleavage; *e*, after numerous cleavages; *f*, blastula (in section); *g*, gastrula, just forming (in section); *h*, gastrula, completed (in section).—After RAEL.

tain principal or constant characteristics of the beginning development which are present in the development of all many-celled animals. The first stage or phenomenon of development is the simple fission of the germ cell into halves (Fig. 39, *b*). These two daughter cells next divide so that there are four cells (Fig. 39, *c*); each of these divides, and this division is repeated until a greater or lesser num-

ber (varying with the various species or groups of animals) of cells is produced (Fig. 39, *d*). The phenomenon of repeated division of the germ cell, and usually the surrounding yolk, is called *cleavage*, and this cleavage is the first stage of development in the case of all many-celled animals. The first division of the germ cell produces usually two equal cells, but in some of the later divisions the new cells formed may not be equal. In some animals all the cleavage cells are of equal size; in some there are two sizes of cells. The germ or embryo animal consists now of a mass of few or many undifferentiated primitive cells lying together and usually forming a sphere (Fig. 39, *e*), or perhaps separated and scattered through the food yolk of the egg. The next stage of development is this: the cleavage cells arrange themselves so as to form a hollow sphere or ball, the cells lying side by side to form the outer circumferential wall of this hollow sphere (Fig. 39, *f*). This is called the *blastula* or *blastoderm* stage of development, and the embryo itself is called the blastula or blastoderm. This stage also is common to all the many-celled animals. The next stage in embryonic development is formed by the bending inward of a part of the blastoderm cell layer, as shown in Fig. 39, *g*. This bending in may produce a small depression or groove; but whatever the shape or extent of the sunken-in part of the blastoderm, it results in distinguishing the blastoderm layer into two parts, a sunken-in portion called the *endoblast* and the other unmodified portion called the *ectoblast*. *Endo-* means "within," and the cells of the endoblast often push so far into the original blastoderm cavity as to come into contact with the cells of the ectoblast and thus obliterate this cavity (Fig. 39, *h*). This third well-marked stage in the embryonic development is called the *gastrula* * stage, and it also

* This gastrula stage is not always formed by a bending in or invagination of the blastoderm, but in some animals is formed by the splitting off or delamination of cells from a definite limited region of

occurs in the development of all or nearly all many-celled animals.

51. Continuity of development.—In the case of a few of the simple many-celled animals the embryo hatches—that is, issues from the egg at the time of or very soon after reaching the gastrula stage. In the higher animals, however, development goes on within the egg or within the body of the mother until the embryo becomes a complex body, composed of many various tissues and organs. Almost all the development may take place within the egg,

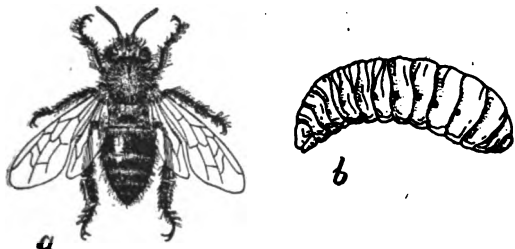


FIG. 40.—Honey-bee. *a*, adult worker; *b*, young or larval worker.

so that when the young animal hatches there is necessary little more than a rapid growth and increase of size to make it a fully developed, mature animal. This is the case with the birds: a chicken just hatched has most of the tissues and organs of a full-grown fowl, and is simply a little hen. But in the case of other animals the young hatches from the egg before it has reached such an advanced stage of development; a young star-fish or young crab or young honey-bee (Fig. 40) just hatched looks very different from its parent. It has yet a great deal of development to undergo before it reaches the structural condition of a fully developed and fully grown star-fish or crab or bee. Thus the development of some animals is almost

the blastoderm. Our knowledge of gastrulation and the gastrula stage is yet far from complete.

wholly embryonic development—that is, development within the egg or in the body of the mother—while the development of other animals is largely post-embryonic or larval development, as it is often called. There is no important difference between embryonic and post-embryonic development. The development is continuous from egg cell to mature animal, and whether inside or outside of an egg it goes on regularly and uninterruptedly.

52. Development after the gastrula stage.—The cells which compose the embryo in the cleavage stage and blastoderm stage, and even in the gastrula stage, are all similar; there is little or no differentiation shown among them. But from the gastrula stage on development includes three important things: the gradual differentiation of cells into various kinds to form the various kinds of animal tissues; the arrangement and grouping of these cells into organs and body parts; and finally the developing of these organs and body parts into the special condition characteristic of the species of animal to which the developing individual belongs. From the primitive undifferentiated cells of the blastoderm, development leads to the special cell types of muscle tissue, of bone tissue, of nerve tissue; and from the generalized condition of the embryo in its early stages development leads to the specialized condition of the body of the adult animal. Development is from the general to the special, as was said years ago by the first great student of development.

53. Divergence of development.—A star-fish, a beetle, a dove, and a horse are all alike in their beginning—that is, the body of each is composed of a single cell, a single structural unit. And they are all alike, or very much alike, through several stages of development; the body of each is first a single cell, then a number of similar undifferentiated cells, and then a hollow sphere consisting of a single layer of similar undifferentiated cells. But soon in the course of development the embryos begin to differ, and as

the young animals get further and further along in the course of their development, they become more and more different until each finally reaches its fully developed mature form, showing all the great structural differences between the star-fish and the dove, the beetle and the horse. That is, all animals begin development alike, but gradually diverge from each other during the course of development.

There are some extremely interesting and significant things about this divergence to which attention should be given. While all animals are alike structurally* at the beginning of development, so far as we can see, they do not all differ at the time of the first divergence in development. This first divergence is only to be noted between two kinds of animals which belong to different great groups or classes. But two animals of different kinds, both belonging to some one great group, do not show differences until later in their development. This can best be understood by an example. All the butterflies and beetles and grasshoppers and flies belong to the great group of animals called *Insecta*, or insects. There are many different kinds of insects, and these kinds can be arranged in subordinate groups, such as the *Diptera*, or flies, the *Lepidoptera*, or butterflies and moths, and so on. But all have certain structural characteristics in common, so that they are comprised in one great group or class—the *Insecta*. Another great group of animals is known as the *Vertebrata*, or back-boned animals. The class *Vertebrata* includes the fishes, the batrachians, the reptiles, the birds, and the mammals, each composing a subordinate group, but all characterized by the possession of a back-

* They are alike structurally, when we consider the cell as the unit of animal structure. That the egg cells of different animals may differ in their fine or ultimate structure, seems certain. For each one of these egg cells is destined to become some one kind of animal, and no other; each is, indeed, an individual in simplest, least developed condition of some one kind of animal, and we must believe that difference in kind of animals depends upon difference in structure in the egg itself.

bone, or, more accurately speaking, of a notochord, a back-bone-like structure. Now, an insect and a vertebrate diverge very soon in their development from each other; but two insects, such as a beetle and a honey-bee, or any two vertebrates, such as a frog and a pigeon, do not diverge from each other so soon. That is, all vertebrate animals diverge in one direction from the other great groups, but all the members of the great group keep together for some time longer. Then the subordinate groups of the Vertebrata, such as the fishes, the birds, and the others diverge, and still later the different kinds of animals in each of these groups diverge from each other. In the illustration (Fig. 41) on the opposite page will be seen pictures of the embryos of various vertebrate animals shown as they appear at different stages or times in the course of development. The embryos of a fish, a salamander, a tortoise, a bird, and a mammal, representing the five principal groups of the Vertebrata, are shown. In the upper row the embryos are in the earliest of all the stages figured, and they are very much alike. They show no obvious characteristics of fish or bird. Yet there are distinctive characteristics of the great class Vertebrata. Any of these embryos could readily be distinguished from an embryonic insect or worm or sea-urchin. In the second row there is beginning to be manifest a divergence among the different embryos, although it would still be a difficult matter to distinguish certainly which was the young fish and which the young salamander, or which the young tortoise and which the young bird. In the bottom row, showing the animals in a later stage of development, the divergence has proceeded so far that it is now plain which is a fish, which batrachian, which reptile, which bird, and which mammal.

54. **The laws or general facts of development.**—That the course of development of any animal from its beginning to fully developed adult form is fixed and certain is readily seen. Every rabbit develops in the same way; every grass-

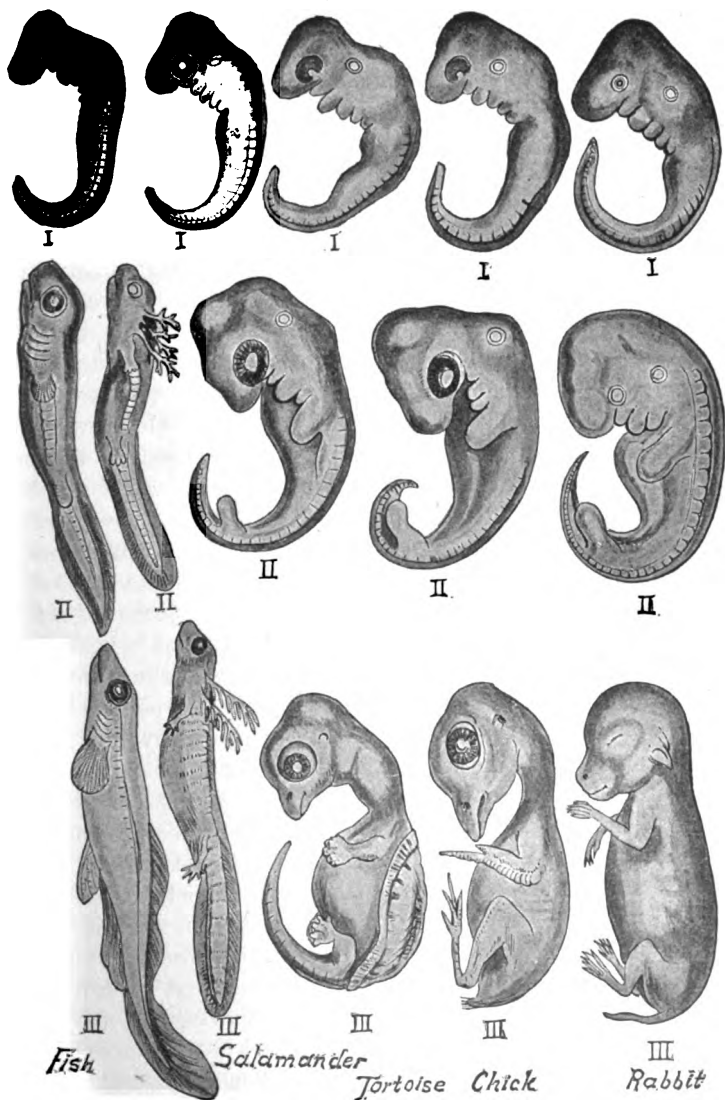


FIG. 41.—Different vertebrate animal in successive embryonic stages. I, first or earliest of the stages figured; II, second of the stages; III, third or latest of the stages.—After HÆCKEL.

hopper goes through the same developmental changes from single egg cell to the full-grown active hopper as every other grasshopper of the same kind—that is, development takes place according to certain natural laws, the laws of animal development. These laws may be roughly stated as follows: All many-celled animals begin life as a single cell, the fertilized egg cell; each animal goes through a certain orderly series of developmental changes which, accompanied by growth, leads the animal to change from single cell to the many-celled, complex form characteristic of the species to which the animal belongs; this development is from simple to complex structural condition; the development is the same for all individuals of one species. While all animals begin development similarly, the course of development in the different groups soon diverges, the divergence being of the nature of a branching, like that shown in the growth of a tree. In the free tips of the smallest branches we have represented the various species of animals in their fully developed condition, all standing clearly apart from each other. But in tracing back the development of any kind of animal, we soon come to a point where it very much resembles or becomes apparently identical with some other kind of animal, and going further back we find it resembling other animals in their young condition, and so on until we come to that first stage of development, that trunk stage, where all animals are structurally alike. To be sure, any animal at any stage in its existence differs absolutely from any other kind of animal, in that it can develop into only its own kind of animal. There is something inherent in each developing animal that gives it an identity of its own. Although in its young stages it may be hardly distinguishable from some other kind of animal in similar stages, it is sure to come out, when fully developed, an individual of the same kind as its parents were or are. The young fish and the young salamander in the upper row in Fig. 41 seem very much alike, but one embryo is sure to

develop into a fish and the other into a salamander. This certainty of an embryo to become an individual of a certain kind is called the law of heredity.

55. The significance of the facts of development.—The significance of the developmental phenomena is a matter about which naturalists have yet very much to learn. It is believed, however, by practically all naturalists that many of the various stages in the development of an animal correspond to or repeat the structural condition of the animal's ancestors. Naturalists believe that all backboned or vertebrate animals are related to each other through being descended from a common ancestor, the first or oldest backboned animal. In fact, it is because all these backboned animals—the fishes, the batrachians, the reptiles, the birds, and the mammals—have descended from a common ancestor that they all have a backbone. It is believed that the descendants of the first backboned animal have in the course of many generations branched off little by little from the original type until there have come to exist very real and obvious differences among the backboned animals—differences which among the living backboned animals are familiar to all of us. The course of development of an individual animal is believed by many naturalists to be a very rapid, and evidently much condensed and changed, recapitulation of the history which the species or kind of animal to which the developing individual belongs has passed through in the course of its descent through a long series of gradually changing ancestors. If this is true, then we can readily understand why the fish and the salamander and tortoise and bird and rabbit are all so much alike in their earlier stages of development, and gradually come to differ more and more as they pass through later and later developmental stages.

Some naturalists believe that the ontogenetic stages are not as significant in throwing light upon the evolutionary history of the species as just indicated. Some think that

when the earlier stages of one species correspond pretty closely with the early stages of another, we have a good basis for making up our minds about relationship between the two species. But it is certainly not obvious why we should have a similarity among the younger stages of different animals and no correspondence among the older stages of more recent animals with the younger stages of more ancient ones. But on the other hand it is certainly true that a too specific application of the broad generalization that ontogeny repeats phylogeny has led to numerous errors of interpreting genealogic relationship.

56. Metamorphosis.—While a young robin when it hatches from the egg or a young kitten at birth resembles its parents, a young star-fish or a young crab or a young butterfly when hatched does not at all resemble its parents. And while the young robin after hatching becomes a fully grown robin simply by growing larger and undergoing comparatively slight developmental changes, the young star-fish or young butterfly not only grows larger, but undergoes some very striking developmental changes; the body changes very much in appearance. Marked changes in the body of an animal during post-embryonic or larval development constitute what is called *metamorphic development*, or the animal is said to undergo or to show *metamorphosis* in its development. Metamorphosis is one of the most interesting features in the life history or development of animals, and it can be, at least as far as its external aspects are concerned, very readily observed and studied.

57. Metamorphosis among insects.—All the butterflies and moths show metamorphosis in their development. So do many other insects, as the ants, bees, and wasps, and all the flies and beetles. On the other hand, many insects do not show metamorphosis, but, like the birds, are hatched from the egg in a condition plainly resembling the parents. A grasshopper (Fig. 42) is a convenient example of an insect without metamorphosis, or rather, as there are, after all,

a few easily perceived changes in its post-embryonic development, of an insect with an "incomplete metamorphosis." The eggs of grasshoppers are laid in little packets of several score half an inch below the surface of the ground. When the young grasshopper hatches from the egg it is of course very small, but it is plainly recognizable as a grasshopper. But in one important character it differs from the adult, and that is in its lack of wings. The adult grasshopper has two pairs of wings; the just hatched young or larval grasshopper has no wings at all. The young grasshopper feeds voraciously and grows rapidly.

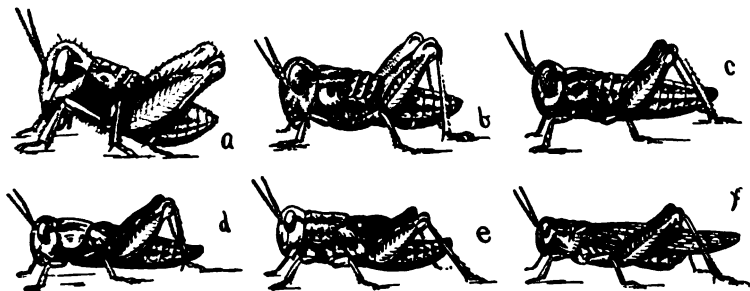


FIG. 42.—Post-embryonic development (incomplete metamorphosis) of the Rocky Mountain locust (*Melanoplus spretus*). a, b, c, d, e, and f, successive developmental stages from just hatched to adult individual.—After EMERTON.

In a few days it molts, or casts its outer skin (not the true skin, but a thin, firm covering or outer body wall composed of a substance called chitin, which is secreted by the cells of the true skin). In this second larval stage there can be seen the rudiments of four wings, in the condition of tiny wing pads on the back of the middle part of the body (the thorax). Soon the chitinous body covering is shed again, and after this molt the wing pads are markedly larger than before. Still another molt occurs, with another increase in size of the developing wings, and after a fifth and last molt the wings are fully developed, and

the grasshopper is no longer in a larval or immature condition, but is full grown and adult.

For example of complete metamorphosis among insects we may choose a butterfly, the large red-brown butterfly

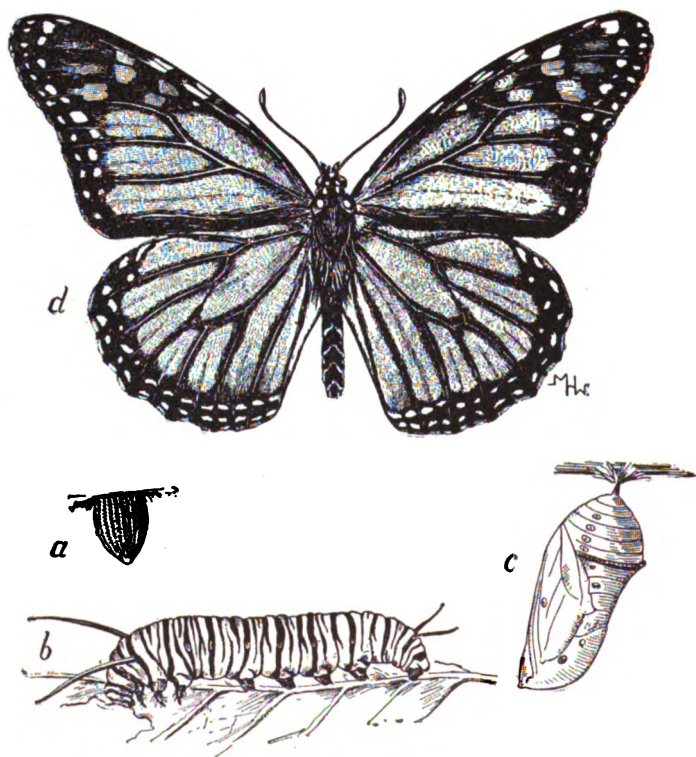


FIG. 43.—Metamorphosis of monarch butterfly (*Anosia plexippus*). *a*, egg; *b*, larva; *c*, pupa; *d*, imago or adult.

common in the United States and called the monarch or milkweed butterfly (*Anosia plexippus*). The eggs (Fig. 43, *a*) of this butterfly are laid on the leaves of various kinds of milkweed (*Asclepias*). The larval butterfly or butterfly larva or caterpillar (as the first young stage of the butter-

flies and moths is usually called), which hatches from the egg in three or four days, is a creature bearing little or no resemblance to the beautiful winged adult. The larva is worm-like, and instead of having three pairs of legs like the butterfly it has eight pairs; it has biting jaws in its mouth with which it nips off bits of the green milkweed leaves, instead of having a long, slender, sucking proboscis for drinking flower nectar as the butterfly has.

The body of the crawling worm-like larva (Fig. 43, *b*) is greenish yellow in color, with broad rings or bands of shining black. It has no wings, of course. It eats voraciously, grows rapidly and molts. But after the molting there is no appearance of rudimentary wings; it is simply a larger worm-like larva. It continues to feed and grow, molting several times, until after the fourth molt it appears no longer as an active, crawling, feed-

ing, worm-like larva, but as a quiescent, non-feeding pupa or chrysalis (Fig. 43, *c*). The immature butterfly is now greatly contracted, and the outer chitinous wall is very thick and firm. It is bright green in color with golden dots. It is fastened by one end to a leaf of the milkweed, where it hangs immovable for from a few days to two weeks. Finally, the chitin wall of the chrysalis splits, and there issues the full-fledged, great, four-winged, red-brown butterfly (Fig. 43, *d*). Truly this is a metamorphosis, and a start-

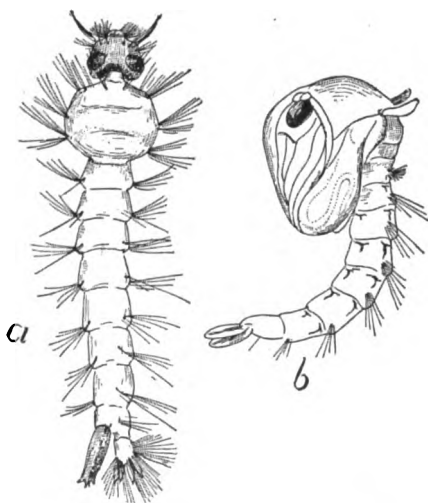


FIG. 44.—Metamorphosis of mosquito (*Culex*).
a, larva; *b*, pupa.

ling one. But we know that development in other animals is a gradual and continuous process, and so it is in the

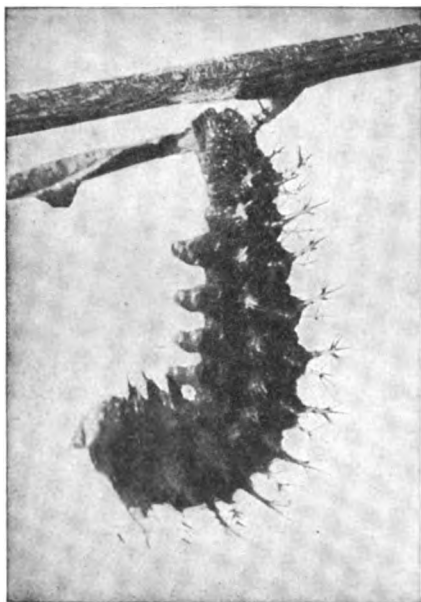


FIG. 45.—Larva of a butterfly just changing into pupa (making last larval molt). Photograph from Nature.

case of the butterfly. The gradual changing is masked by the outer covering of the body in both larva and pupa. It is only at each molting or throwing off of this unchanging, unyielding chitin armor that we perceive how far this change has gone. The longest time of concealment is that during the pupal or chrysalis stage, and the results of the changing or development when finally revealed by the splitting of the pupal case are hence the most striking.

58. Metamorphosis of the toad.—Metamorphosis is found in the development of numerous other animals, as well as among the insects. Certain cases are familiar to all—the metamorphosis of the frogs and toads (Fig. 46). The eggs of the toad are arranged in long strings or ribbons in a transparent jelly-like substance. These jelly ribbons with the small, black, bead-like eggs in them are wound around the stems of submerged plants or sticks near the shores of the pond. From each egg hatches a tiny, wriggling tadpole, differing nearly as much from a full-grown toad as a caterpillar differs from a butterfly. The tadpoles feed on

the microscopic plants to be found in the water, and swim easily about by means of the long tail. The very young tadpoles remain underneath the surface of the water all the time, breathing the air which is mixed with water by means of gills. But as they become older and larger they come often to the surface of the water. Lungs are developing inside the body, and the tadpole is beginning to breathe as a land animal, although it still breathes partly by means of gills, that is, as an aquatic animal. Soon it is apparent that although the tadpole is steadily and rapidly growing larger, its tail is growing shorter and smaller instead of larger. At the same time, fore and hind legs bud out and rapidly take

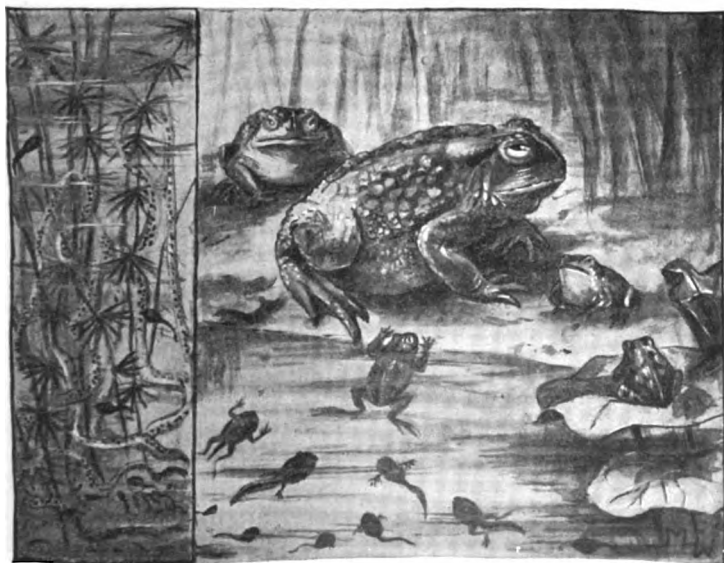


FIG. 46.—Metamorphosis of the toad (partly after GAGE). At left the strings of eggs, in water the various tadpole or larval stages, and on bank the adult toads.

form and become functional. By the time that the tail gets very short, indeed, the young toad is ready to leave the water and live as a land animal. On land the toad lives, as

we know, on insects and snails and worms. The metamorphosis of the toad is not so striking as that of the butterfly, but if the tadpole were inclosed in an unchanging opaque body wall while it was losing its tail and getting its legs, and this wall were to be shed after these changes were made, would not the metamorphosis be nearly as extraordi-

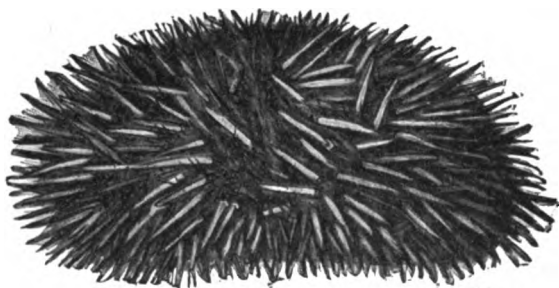


FIG. 47.—Metamorphosis of sea-urchin. Upper figure the adult, lower figure the pluteus larva.



nary as in the case of the butterfly? But in the metamorphosis of the toad we can see the gradual and continuous character of the change.

59. Metamorphosis among other animals.—Many other animals, besides insects and frogs and toads, undergo metamorphosis. The just-hatched sea-urchin does not resemble a fully developed sea-urchin at all. It is a minute worm-like creature, provided with cilia or vibratile hairs, by means of which it swims freely about. It changes next into a curious bootjack-shaped body called the pluteus stage (Fig. 47). In the pluteus a skeleton of lime is formed, and the final true sea-urchin body begins to appear inside the pluteus,

developing and growing by using up the body substance of the pluteus. Star-fishes, which are closely related to sea-urchins, show a similar metamorphosis, except that there is no pluteus stage, the true star-fish-shaped body forming, within and at the expense of the first larval stage, the ciliated free-swimming stage.

A young crab just issued from the egg (Fig. 48) is a very different appearing creature from the adult or fully developed crab. The body of the crab in its first larval stage is composed of a short, globular portion, fur-

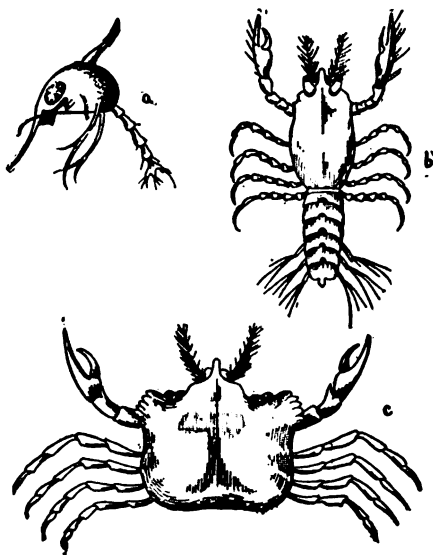


FIG. 48.—Metamorphosis of the crab. *a*, the zoëa stage; *b*, the megalops; *c*, the adult.

nished with conspicuous long spines and a relatively long, jointed tail. This is called the zoëa stage. The zoëa changes into a stage called the megalops, which has many characteristics of the adult crab condition, but differs especially from it in the possession of a long, segmented tail, and in having the front half of the body longer than wide. The crab in the megalops stage looks very much like a tiny lobster or shrimp. The tail soon disappears and the body widens, and the final stage is reached.

In many families of fishes the changes which take place in the course of the life cycle are almost as great as in the case of the insect or the toad. In the lady-fish (*Albula vulpes*) the very young (Fig. 49) are ribbon-like in form,

with small heads and very loose texture of the tissues, the body substance being jelly-like and transparent. As the fish grows older the body becomes more compact, and therefore

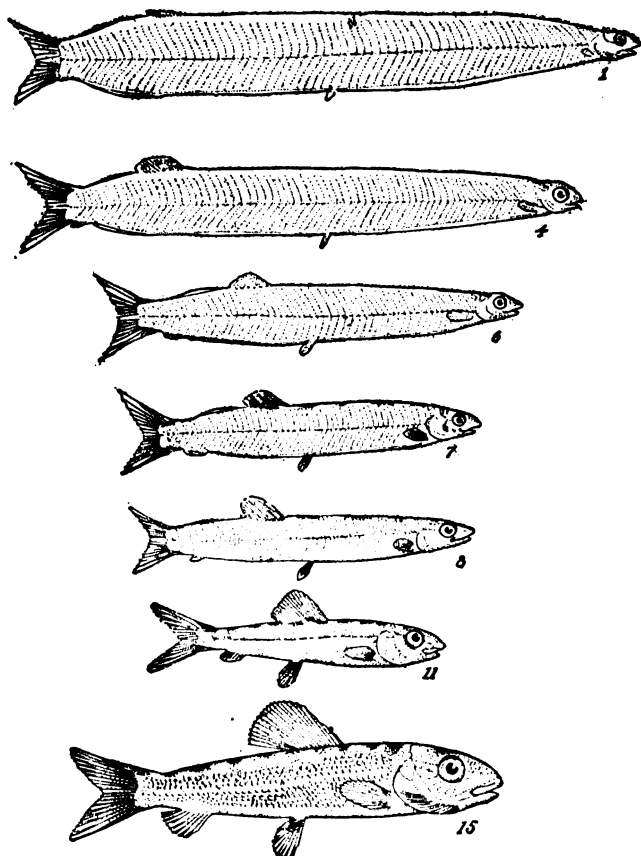


FIG. 49.—Stages in the post-embryonic development of the lady-fish (*Albula vulpes*), showing metamorphosis.—After C. H. GILBERT.

shorter and slimmer. After shrinking to the texture of an ordinary fish, its growth in size begins normally, although

it has steadily increased in actual weight. Many herring, eels, and other soft-bodied fishes pass through stages similar to those seen in the lady-fish. Another type of development is illustrated in the sword-fish. The young has a bony head, bristling with spines. As it grows older the spines disappear, the skin grows smoother, and, finally, the bones of the upper jaw grow together, forming a prolonged sword, the teeth are lost and the fins become greatly modified. Fig. 50 shows three of these stages of growth. The

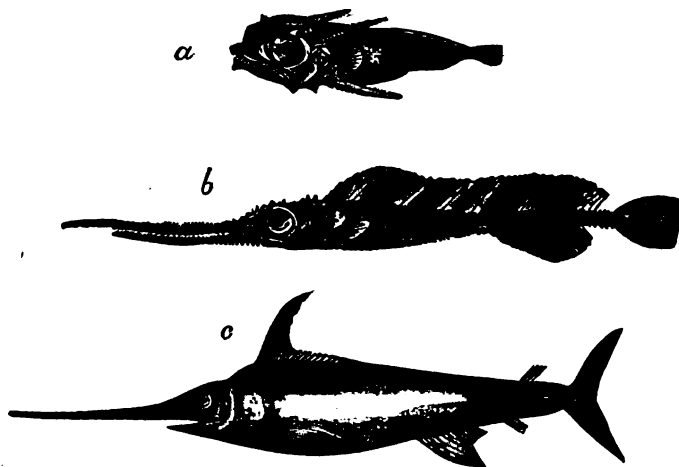


FIG. 50.—Three stages in the development of the sword-fish (*Xiphias gladius*).
a, very young; b, older; c, adult.—Partly after LÜTKEN.

flounder or flat-fish (Fig. 51) when full grown lies flat on one side when swimming or when resting in the sand on the bottom of the sea. The eyes are both on the upper side of the body, and the lower side is blind and colorless. When the flounder is hatched it is a transparent fish, broad and flat, swimming vertically in the water, with an eye on each side. As its development (Fig. 52) goes on it rests itself obliquely on the bottom, the eye of the lower side turns upward, and as growth proceeds it passes gradually

around the forehead, its socket moving with it, until both eyes and sockets are transferred by twisting of the skull to

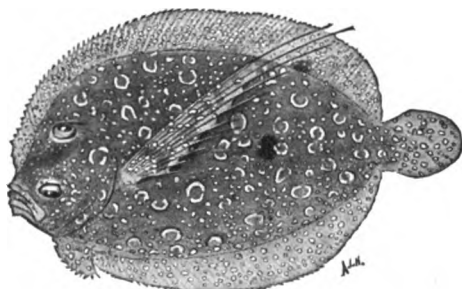


FIG. 51.—The wide-eyed flounder (*Platophrys lunatus*). Adult, showing both eyes on upper side of head.

the upper side. In some related forms or soles the small eye passes through the head and not around it, appearing finally in the same socket with the other eye.

Thus in almost all the great groups of animals we find certain kinds which show metamorphosis in their post-embryonic development. But metamorphosis is simply development; its striking and extraordinary features are usually due to the fact that the orderly, gradual course of the development is revealed to us only occasionally, with the result of giving the impression that the development is proceeding by leaps and bounds from one strange stage to

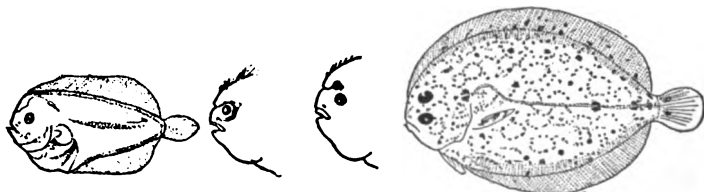


FIG. 52.—Development of a flounder (after EMERY). The eyes in the young flounder are arranged normally, one on each side of head.

another. If metamorphosis is carefully studied it loses its aspect of marvel, although never its great interest.

60. Duration of life.—After an animal has completed its development it has but one thing to do to complete its life cycle, and that is the production of offspring. When it has laid eggs or given birth to young, it has insured the beginning of a new life cycle. Does it now die? Is the business of its life accomplished? There are many animals which die immediately or very soon after laying eggs. The May-flies—ephemeral insects which issue as winged adults from ponds or lakes in which they have spent from one to three years as aquatic crawling or swimming larvæ, flutter about for an evening, mate, drop their packets of fertilized eggs into the water, and die before the sunrise—are extreme examples of the numerous kinds of animals whose adult life lasts only long enough for mating and egg-laying. But elephants live for two hundred years. Whales probably live longer. A horse lives about thirty years, and so may a cat or toad. A sea-anemone, which was kept in an aquarium, lived sixty-six years. Cray-fishes may live twenty years. A queen bee was kept in captivity for fifteen years. Most birds have long lives—the small song birds from eight to eighteen years, and the great eagles and vultures up to a hundred years or more. On the other hand, among all the thousands of species of insects, the individuals of very few indeed live more than a year; the adult life of most insects being but a few days or weeks, or at best months. Even among the higher animals, some are very short-lived. In Japan is a small fish (*Solauz*) which probably lives

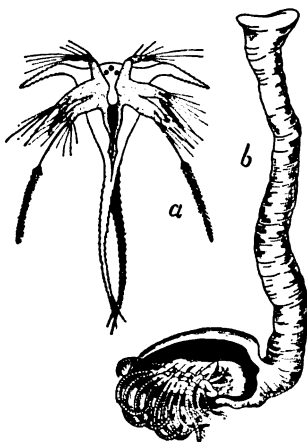


FIG. 53.—Metamorphosis of a barnacle (*Lepas*). *a*, larva; *b*, adult.

but a year, ascending the rivers in numbers when young in the spring, the whole mass of individuals dying in the fall after spawning.

Naturalists have sought to discover the reason for these extraordinary differences in the duration of life of different animals, and while it can not be said that the reason or reasons are wholly known, yet the probability is strong that the duration of life is closely connected with, or dependent upon, the conditions attending the production of offspring. It is not sufficient, as we have learned from our study of the multiplication of animals (Chapter III), that an adult animal shall produce simply a single new individual of its kind, or even only a few. It must produce many, or if it produces comparatively few it must devote great care to the rearing of these few, if the perpetuation of the species is to be insured. Now, almost all long-lived animals are species which produce but few offspring at a time, and reproduce only at long intervals, while most short-lived animals produce a great many eggs, and these all at one time. Birds are long-lived animals; as we know, most of them lay eggs but once a year, and lay only a few eggs each time. Many of the sea birds which swarm in countless numbers on the rocky ocean islets and great sea cliffs lay only a single egg once each year. And these birds, the guillemots and murre and auks, are especially long-lived. Insects, on the contrary, usually produce many eggs, and all of them in a short time. The May-fly, with its one evening's lifetime, lets fall from its body two packets of eggs and then dies. Thus the shortening of the period of reproduction with the production of a great many offspring seem to be always associated with a short adult lifetime; while a long period of reproduction with the production of few offspring at a time and care of the offspring are associated with a long adult lifetime.

There seems also to be some relation between the size of animals and the length of life. As a general rule,

large animals are long-lived and small animals have short lives.

61. Death.—At the end comes death. After the animal has completed its life cycle, after it has done its share toward insuring the perpetuation of its species, it dies. It may meet a violent death, may be killed by accident or by enemies, before the life cycle is completed. And this is the fate of the vast majority of animals which are born or hatched. Or death may come before the time for birth or hatching. Of the millions of eggs laid by a fish, each egg a new fish in simplest stage of development, how many or rather how few come to maturity, how few complete the cycle of life!

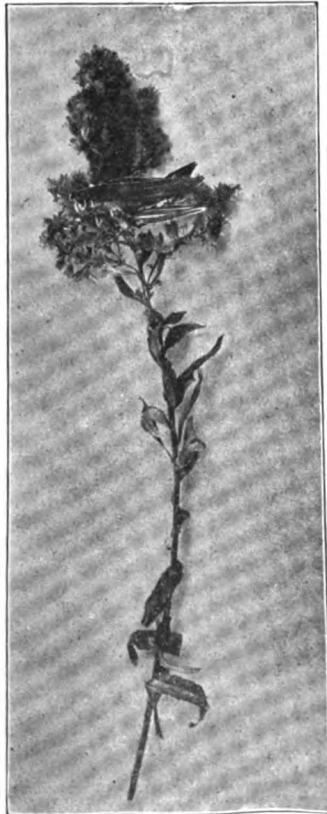
Of death we know the essential meaning. Life ceases and can never be renewed in the body of the dead animal. It is important that we include the words "can never be renewed," for to say simply that "life ceases," that is, that the performance of the life processes or functions ceases, is not really death. It is easy to distinguish in most cases between life and death, between a live animal and a dead one, yet there are cases of apparent death or a semblance of death which are very puzzling. The test of life is usually taken to be the performance of life functions, the assimilation of food and excretion of waste, the breathing in of oxygen, and breathing out of carbonic-acid gas, movement, feeling, etc. But some animals can actually suspend all of these functions, or at least reduce them to such a minimum that they can not be perceived by the strictest examination, and yet not be dead. That is, they can renew again the performance of the life processes. Bears and some other animals, among them many insects, spend the winter in a state of death-like sleep. Perhaps it is but sleep; and yet hibernating insects can be frozen solid and remain frozen for weeks and months, and still retain the power of actively living again in the following spring. Even more remarkable is the case of certain minute animals called *Ro-*

tatoria and of others called *Tardigrada*, or bear-animalcules. These bear-animalcules live in water. If the water dries up, the animalcules dry up too; they shrivel up into formless little masses and become desiccated. They are thus simply dried-up bits of organic matter; they are organic dust. Now, if after a long time—years even—one of these organic dust particles, one of these dried-up bear-animalcules is put into water, a strange thing happens. The body swells and stretches out, the skin becomes smooth instead of all wrinkled and folded, and the legs appear in normal shape. The body is again as it was years before, and after a quarter of an hour to several hours (depending on the length of time the animal has lain dormant and dried) slow movements of the body parts begin, and soon the animalcule crawls about, begins again its life where it had been interrupted. Various other small animals, such as vinegar eels and certain Protozoa, show similar powers. Certainly here is an interesting problem in life and death.

When death comes to one of the animals with which we are familiar, we are accustomed to think of its coming to the whole body at some exact moment of time. As we stand beside a pet which has been fatally injured, we wait until suddenly we say, "It is dead." As a matter of fact, it is difficult to say when death occurs. Long after the heart ceases to beat, other organs of the body are alive—that is, are able to perform their special functions. The muscles can contract for minutes or hours (for a short time in warm-blooded, for a long time in cold-blooded animals) after the animal ceases to breathe and its heart to beat. Even longer live certain cells of the body, especially the amoeboid white blood-corpuscles. These cells, very like the *Amœba* in character, live for days after the animal is, as we say, dead. The cells which line the tracheal tube leading to the lungs bear cilia or fine hairs which they wave back and forth. They continue this movement for days after the heart has ceased beating. Among cold-

blooded animals, like snakes and turtles, complete cessation of life functions comes very slowly, even after the body has been literally cut to pieces.

Thus it is essential in defining death to speak of a complete and permanent cessation of the performance of the life processes.



A grasshopper (*Melanoplus differentialis*) killed by disease caused by a parasitic fungus. On golden-rod.

CHAPTER VI

THE PRIMARY CONDITIONS OF ANIMAL LIFE

62. Primary conditions and special conditions.—Certain primary conditions are necessary for the existence of all animals. We know that fishes can not live very long out of water, and that birds can not live in water. These, however, are special conditions which depend on the special structure and habits of these two particular kinds of backboned animals. But the necessity of a constant and sufficient supply of air is a necessity common to both; it is one of the primary conditions of their life. All animals must have air. Similarly both fishes and birds, and all other animals as well, must have food. This is another one of the primary conditions of animal life. That backboned animals must find somehow a supply of salts or compounds of lime to form into bones is a special condition peculiar to these animals. Other animals having shells or teeth composed of carbonate or phosphate of lime are subject to the same special demand, but many animals have no hard parts, and therefore need no lime.

63. Food.—All the higher plants, those that are green (chlorophyll-bearing), can make their living substance out of inorganic matter alone—that is, use inorganic substances as food. But animals can not do this. They must have already formed organic matter for food. This organic matter may be the living or dead tissues of plants, or the living or dead tissues of animals. For the life of animals it is necessary that other organisms live, or have lived. It is this need which primarily distinguishes an animal from a

plant. Animals can not exist without plants. The plants furnish all animals with food, either directly or indirectly. The amount of food and the kinds of food required by various kinds of animals are special conditions depending on the size, the degree of activity, the structural character of the body, etc., of the animal in question. Those which do the most need most. Those with warmest blood, greatest activity, and most rapid change of tissues are most dependent on abundance, regularity, and fitness of their food. As we well know, an animal can live for a longer or shorter time without food. Men have fasted for a month, or even two months. Among cold-blooded animals, like the reptiles, the general habit of food taking is that of an occasional gorging, succeeded by a long period of abstinence. Many of the lower animals can go without food for surprisingly long periods without loss of life. But the continued lack of food results inevitably in death. Any animal may be starved in time.

If water be held not to be included in the general conception of food, then special mention must be made of the necessity of water as one of the primary conditions of animal life. Protoplasm, the basis of life, is a fluid, although thick and viscous. To be fluid its components must be dissolved or suspended in water. In fact, all the truly living substance in an animal's body contains water. The water necessary for the animal may be derived from the other food, all of which contains water in greater or less quantity, or may be taken apart from the other food, by drinking or by absorption through the skin. Sheep are seldom seen to drink, for they find almost enough water in their green food. Fur seals never drink, for they absorb the water needed through pores in the skin.

64. Oxygen.—Animals must have air in order to live, but the essential element of the air which they need is its oxygen. For the metabolism of the body, for the chemical

changes which take place in the body of every living animal, a supply of oxygen is required. This oxygen is derived directly or indirectly from the air. The atmosphere of the earth is composed of 79.02 parts of nitrogen (including argon), .03 parts of carbonic acid, and 20.95 parts of oxygen. Thus all the animals which live on land are enveloped by a substance containing nearly 21 per cent of oxygen. But animals can live in an atmosphere containing much less oxygen. Certain mammals, experimented on, lived without difficulty in an atmosphere containing only 14 per cent of oxygen; when the oxygen was reduced to 7 per cent serious disturbances were caused in the animal's condition, and death by suffocation ensued when 3 per cent of oxygen was left in the atmosphere. Animals which live in water get their oxygen, not from the water itself (water being composed of hydrogen and oxygen), but from air which is mechanically mixed with the water. Fishes breathe the air which is mixed with or dissolved in the water. This scanty supply therefore constitutes their atmosphere, for in water from which all air is excluded no animal can breathe. Whatever the habits of life of the animal, whether it lives on the land, in the ground, or in the water, it must have oxygen or die.

65. Temperature, pressure, and other conditions.—Some physiologists include among the primary or essential general conditions of animal life such conditions as favorable temperature and favorable pressure. It is known from observation and experiment that animals die when a too low or a too high temperature prevails. The minimum or maximum of temperature between which limits an animal can live varies much among different kinds of animals. It is familiar knowledge that many kinds of animals can be frozen and yet not be killed. Insects and other small animals may lie frozen through a winter and resume active life again in the spring. An experimenter kept certain fish frozen in blocks of ice at a temperature of -15° C.

for some time and then gradually thawed them out unhurt. Only very hardy kinds adapted to the cold would, however, survive such treatment. There is no doubt that every part of the body, all of the living substance, of these fish was frozen, for specimens at this temperature could be broken and pounded up into fine ice powder. But a temperature of -20° C. killed the fish. Frogs lived after being kept at a temperature of -28° C., centipeds at -50° C., and certain snails endured a temperature of -120° C. without dying. At the other extreme, instances are known of animals living in water (hot springs or water gradually heated with the organisms in it) of a temperature as high as 50° C. Experiments with *Amœbæ* show that these simplest animals contract and cease active motion at 35° C., but are not killed until a temperature of 40° to 45° C. is reached. The little fish called blob or miller's thumb (*Cottus icталops*) has been seen lying boiled in the bottom of the hot springs in the Yellowstone Park; but it must have entered these springs through streams of a temperature little below the boiling point.

The pressure or weight of the atmosphere on the surface of the earth is nearly fifteen pounds on each square inch. This pressure is exerted equally in all directions, so that an object on the earth's surface sustains a pressure on each square inch of its surface exposed to the air of fifteen pounds. Thus all animals living on the earth's surface or near it live under this pressure, and know no other condition. For this reason they do not notice it. The animals that live in water, however, sustain a much greater pressure, this pressure increasing with the depth. Certain ocean fishes live habitually at great depths, as two to five miles, where the pressure is equivalent to that of many hundred atmospheres. If these fishes are brought to the surface their eyes bulge out fearfully, being pushed out through reduced expansion; their scales fall off because of the great expansion of the skin, and the stomach is pushed

out from the mouth till it is wrong side out. Indeed, the bodies sometimes burst. Their bodies are accustomed to this great pressure, and when this outside pressure is suddenly removed the body may be bursted. Sometimes such a fish is raised from its proper level by a struggle with its prey, when both captor and victim may be destroyed by the expansion of the body. Some fishes die on being taken out of water through the swelling of the air bladder and the bursting of its blood-vessels. If an animal which lives normally on the surface of the earth is taken up a very high mountain or is carried up in a balloon to a great altitude where the pressure of the atmosphere is much less than it is at the earth's surface, serious consequences may ensue, and if too high an altitude is reached death occurs. This death may be in part due to the difficulty in breathing in sufficient oxygen to maintain life, but it is probably chiefly due to disturbances caused by the removal of the pressure to which the body is accustomed and is structurally adapted to withstand. A famous balloon ascension was made in Paris in 1875 by three men. After the balloon had reached a height of nearly 24,000 feet (almost five miles) the men began to lose consciousness. On the sinking of the balloon to about 20,000 feet the men regained consciousness again and threw out ballast so that the balloon rose to a height of over 25,000 feet. This time all three became wholly unconscious, and on the balloon sinking again only one regained consciousness. The other two died in the foolhardy experiment. All living animals are accustomed to live under a certain pressure, and there are evidently limits of maximum or minimum pressure beyond which no animal at present existing can go and remain alive.

But in the case both of temperature and pressure conditions it is easy to conceive that animals might exist which could live under temperature and pressure conditions not included between the minimum and maximum limits of each

as determined by animals so existing. But it is impossible to conceive of animals which could live without oxygen or without organic food. The necessities of oxygen and organic food (and water) are the primary or essential conditions for the existence of any animals.

Of course, we might include such conditions, among the primary conditions, as the light and heat of the sun, the action of gravitation, and other physical conditions without which existence or life of any kind would be impossible on this earth. But we here consider by "primary conditions of animal life" rather those necessities of living animals as opposed to the necessities of living plants. Neither animals nor plants could exist without the sun, whence they derive directly or indirectly all their energy.

66. Difference between animals and plants.—It is easy to distinguish between the animal and plant when a butterfly is fluttering about a blossoming cherry tree or a cow feeding in a field of clover. It is not so easy, if it is, indeed, possible, to say which is plant and which is animal when the simplest plants are compared with the simplest animals. It is almost impossible to so define animals as to distinguish all of them from all plants, or so to define plants as to distinguish all of them from all animals. While most animals have the power of locomotion, some, like the sponges and polyps and barnacles and numerous parasites, are fixed. While most plants are fixed, some of the low aquatic forms have the power of spontaneous locomotion, and all plants have some power of motion, as especially exemplified in the revolution of the apex of the growing stem and root, and the spiral twisting of tendrils, and in the sudden closing of the leaves of the sensitive plant when touched. Among the green or chlorophyll-bearing plants the food consists chiefly of inorganic substances, especially of carbon which is taken from the carbonic-acid gas in the atmosphere, and of water. But some green-leaved plants feed also in part on organic food.

Such are the pitcher-plants and sun-dews, and Venus-fly-traps, which catch insects and use them for food nutrition. But there are many plants, the fungi, which are not green—that is, which do not possess chlorophyll, the substance on which seems to depend the power to make organic matter out of inorganic substances. These plants feed on organic matter as animals do. The cells of plants (in their young stages, at least) have a wall composed of a peculiar carbohydrate substance called cellulose, and this cellulose was for a long time believed not to occur in the body of animals. But now it is known that certain sea-squirts (Tunicata) possess cellulose. It is impossible to find any set of characteristics, or even any one characteristic, which is possessed only by plants or only by animals. But nearly all of the many-celled plants and animals may be easily distinguished by their general characteristics. The power of breaking up carbonic-acid gas into carbon and oxygen and assimilating the carbon thus obtained, the presence of chlorophyll, and the cell walls formed of cellulose, are characteristics constant in all typical plants. In addition, the fixed life of plants, and their general use of inorganic substances for food instead of organic, are characteristics readily observed and practically characteristic of many-celled plants. When the thousands of kinds of one-celled organisms are compared, however, it is often a matter of great difficulty or of real impossibility to say whether a given organism should be assigned to the plant kingdom or to the animal kingdom. In general the distinctive characters of plants are grouped around the loss of the power of locomotion and related to or dependent upon it.

67. Living organic matter and inorganic matter.—It would seem to be an easy matter to distinguish an organism—that is, a living animal or plant—from an inorganic substance. It is easy to distinguish a dove or a sunflower from stone, and practically there never is any difficulty in making such distinctions. But when we try to define living organic matter,

and to describe those characteristics which are peculiar to it, which absolutely distinguish it from inorganic matter, we meet with some difficulties. At least many of the characteristics commonly ascribed to organisms, as peculiar to them, are not so. The possession of organs, or the composition of the body of distinct parts, each with a distinct function, but all working together, and depending on each other, is as true of a steam-engine as of a horse. That the work done by the steam-engine depends upon fuel is true; but so it is that the work done by the horse depends upon fuel, or food as we call it in the case of the animal. The oxidation or burning of this fuel in the engine is wholly comparable with the oxidation of the food, or the muscle and fat it is turned into, in the horse's body. The composition of the bodies of animals and plants of tiny structural units, the cells, is in many ways comparable with the composition of some rocks of tiny structural units, the crystals. But not to carry such rather quibbling comparisons too far, it may be said that organisms are distinguished from organic substances by the following characteristics: Organization; the power to make over inorganic substances into organic matter, or the changing of organic matter of one kind, as plant matter, into another kind, as animal matter; motion, the power of spontaneous movement in response to stimuli; sensation, the power of being sensible of external stimuli; reproduction, the power of producing new beings like themselves; and adaptation, the power of responding to external conditions in a way useful to the organism. Through adaptation organisms continue to exist despite the changing of conditions. If the conditions surrounding an inorganic body change, even gradually, the inorganic body does not change to adapt itself to these conditions, but resists them until no longer able to do so, when it loses its identity or integrity.

CHAPTER VII

THE CROWD OF ANIMALS AND THE STRUGGLE FOR EXISTENCE

68. **The crowd of animals.**—All animals feed upon living organisms, or on their dead bodies. Hence each animal throughout its life is busy with the destruction of other organisms, or with their removal after death. If those creatures upon which others feed are to hold their own, there must be enough born or developed to make good the drain upon their numbers. If the plants did not fill up their ranks and make good their losses, the animals that feed on them would perish. If the plant-eating animals were destroyed, the flesh-eating animals would in turn disappear. But, fortunately, there is a vast excess in the process of reproduction. More plants sprout than can find room to grow. More animals are born than can possibly survive. The process of increase among animals is correctly spoken of as multiplication. Each species tends to increase in geometric ratio, but as it multiplies its members it finds the world already crowded with other species doing the same thing. A single pair of any species whatsoever, if not restrained by adverse conditions, would soon increase to such an extent as to fill the whole world with its progeny. An annual plant producing two seeds only would have 1,048,576 descendants at the end of twenty-one years, if each seed sprouted and matured. The ratio of increase is therefore a matter of minor importance. It is the ratio of net increase above loss which determines the fate of a species. Those species increase in numbers whose gain exceeds

the death rate, and those which "live beyond their means" must sooner or later disappear. One of the most abundant of birds is the fulmar petrel, which lays but one egg yearly. It has but few enemies, and this low rate of increase suffices to cover the seas within its range with petrels.

It is difficult to realize the inordinate numbers in which each species would exist were it not for the checks produced by the presence of other animals. Certain Protozoa at their normal rate of increase, if none were devoured or destroyed, might fill the entire ocean in about a week. The conger-eel lays, it is said, 15,000,000 eggs. If each egg grew up to maturity and reproduced itself in the same way in less than ten years the sea would be solidly full of conger-eels. If the eggs of a common house-fly should develop, and each of its progeny should find the food and temperature it needed, with no loss and no destruction, the people of a city in which this might happen could not get away soon enough to escape suffocation from a plague of flies. Whenever any insect is able to develop a large percentage of the eggs laid, it becomes at once a plague. Thus originate plagues of grasshoppers, locusts, and caterpillars. But the crowd of life is such that no great danger exists. The scavenger destroys the decaying flesh where the fly would lay its eggs. Minute creatures, insects, bacteria, Protozoa are parasitic within the larva and kill it. Millions of flies perish for want of food. Millions more are destroyed by insectivorous birds, and millions are slain by parasites. The final result is that from year to year the number of flies does not increase. Linnæus once said that "three flies would devour a dead horse as quickly as a lion." Equally soon would it be devoured by three bacteria, for the decay of the horse is due to the decomposition of its flesh by these microscopic plants which feed upon it. "Even slow-breeding man," says Darwin, "has doubled in twenty-five years. At this rate in less than a thousand years there would literally not be standing room for his progeny. The elephant is reckoned the slow-

est breeder of all known animals. It begins breeding when thirty years old and goes on breeding until ninety years old, bringing forth six young in the interval, and surviving till a hundred years old. If this be so, after about eight hundred years there would be 19,000,000 elephants alive, descended from the first pair." A few years more of the unchecked multiplication of the elephant and every foot of land on the earth would be covered by them.

Yet the number of elephants does not increase. In general, the numbers of every species of animal in the state of Nature remain about stationary. Under the influence of man most of them slowly diminish. There are about as many squirrels in the forest one year as another, about as many butterflies in the field, about as many frogs in the pond. Wolves, bears, deer, wild ducks, singing birds, fishes, tend to grow fewer and fewer in inhabited regions, because the losses from the hand of man are added to the losses in the state of Nature.

It has been shown that at the normal rate in increase of English sparrows, if none were to die save of old age, it would take but twenty years to give one sparrow to every square inch in the State of Indiana. Such an increase is actually impossible, for more than a hundred other species of similar birds are disputing the same territory with the power of increase at a similar rate. There can not be food and space for all. With such conditions a struggle is set up between sparrow and sparrow, between sparrow and other birds, and between sparrow and the conditions of life. Such a conflict is known as the struggle for existence.

69. **The struggle for existence.**—The struggle for existence is threefold: (*a*) among individuals of one species, as sparrow and sparrow; (*b*) between individuals of different species, as sparrow with bluebird or robin; and (*c*) with the conditions of life, as the effort of the sparrow to keep warm in winter and to find water in summer. All three forms of this struggle are constantly operative and with

every species. In some regions the one phase may be more destructive, in others another. Where the conditions of life are most easy, as in the tropics, the struggle of species with species, of individual with individual, is the most severe.

No living being can escape from any of these three phases of the struggle for existence. For reasons which we shall see later, it is not well that any should escape, for "the sheltered life," the life withdrawn from the stress of effort, brings the tendency to degeneration.

Because of the destruction resulting from the struggle for existence, more of every species are born than can possibly find space or food to mature. The majority fail to reach their full growth because, for one reason or another, they can not do so. All live who can. Each strives to feed itself, to save its own life, to protect its young. But with all their efforts only a portion of each species succeed.

70. Selection by Nature.—But the destruction in Nature is not indiscriminate. In the long run those least fitted to resist attack are the first to perish. It is the slowest animal which is soonest overtaken by those which feed upon it. It is the weakest which is crowded away from the feeding-place by its associates. It is the least adapted which is first destroyed by extremes of heat and cold. Just as a farmer improves his herd of cattle by destroying his weakest or roughest calves, reserving the strong and fit for parentage, so, on an inconceivably large scale, the forces of Nature are at work purifying, strengthening, and fitting to their surroundings the various species of animals. This process has been called natural selection, or the survival of the fittest. But by fittest in this sense we mean only best adapted to the surroundings, for this process, like others in Nature, has itself no necessarily moral element. The song-bird becomes through this process more fit for the song-bird life, the hawk becomes more capable of killing and tear-

ing, and the woodpecker better fitted to extract grubs from the tree.

In the struggle of species with species one may gain a little one year and another the next, the numbers of each species fluctuating a little with varying circumstances, but after a time, unless disturbed by the hand of man, a point will be reached when the loss will almost exactly balance the increase. This produces a condition of apparent equilibrium. The equilibrium is broken when any individual or group of individuals becomes capable of doing something more than hold its own in the struggle for existence.

When the conditions of life become adverse to the existence of a species it has three alternatives, or, better, one of three things happens, namely, migration, adaptation, extinction. The migration of birds and some other animals is a systematic changing of environment when conditions are unfavorable to life. When the snow and ice come, the fur-seal forsakes the islands on which it breeds, and which are its real home, and spends the rest of the year in the open sea, returning at the close of winter. Some other animals migrate irregularly, removing from place to place as conditions become severe or undesirable. The Rocky Mountain locusts, which breed on the great plateau along the eastern base of the Rocky Mountains, sometimes increase so rapidly in numbers that they can not find enough food in the scanty vegetation of this region. Then great hosts of them fly high into the air until they meet an air current moving toward the southeast. The locusts are borne by this current or wind hundreds of miles, until, when they come to the great grain-growing Mississippi Valley, they descend and feed to their hearts' content, and to the dismay of the Nebraska and Kansas farmer. These great forced migrations used to occur only too often, but none has taken place since 1878, and it is probable that none will ever occur again. With the settlement of the Rocky Mountain plateau by farmers, food is plenty at home. And the constant fight-

ing of the locusts by the farmers, by plowing up their eggs, and crushing and burning the young hoppers, keeps down their numbers.

Another animal of interesting migratory habits is the lemming, a mouse-like animal nearly as large as a rat, which lives in the arctic regions. At intervals varying from five to twenty years the cultivated lands of Norway and Sweden, where the lemming is ordinarily unknown, are overrun by vast numbers of these little animals. They come as an army, steadily and slowly advancing, always in the same direction, and "regardless of all obstacles, swimming across streams and even lakes of several miles in breadth, and committing considerable devastation on their line of march by the quantity of food they consume. In their turn they are pursued and harassed by crowds of beasts and birds of prey, as bears, wolves, foxes, dogs, wild cats, stoats, weasels, eagles, hawks, and owls, and never spared by man; even the domestic animals not usually predaceous, as cattle, foals, and reindeer, are said to join in the destruction, stamping them to the ground with their feet and even eating their bodies. Numbers also die from disease apparently produced from overcrowding. None ever return by the course by which they came, and the onward march of the survivors never ceases until they reach the sea, into which they plunge, and swimming onward in the same direction as before perish in the waves." One of these great migrations lasts for from one to three years. But it always ends in the total destruction of the migrating army. But the migration may be of advantage to the lemmings which remain in the original breeding grounds, leaving them with enough food, so that, on the whole, the migration results in gain to the species.

But most animals can not migrate to their betterment. In that case the only alternatives are adaptation or destruction. Some individuals by the possession of slight advantageous variations of structure are able to meet the new

demands and survive, the rest die. The survivors produce young similarly advantageously different from the general type, and the adaptation increases with successive generations.

71. Adjustment to surroundings a result of natural selection.—To such causes as these we must ascribe the nice adjustment of each species to its surroundings. If a species or a group of individuals can not adapt itself to its environment, it will be crowded out by others that can do so. The former will disappear entirely from the earth, or else will be limited to surroundings with which it comes into perfect adjustment. A partial adjustment must with time become a complete one, for the individuals not adapted will be exterminated in the struggle for life. In this regard very small variations may lead to great results. A side issue apparently of little consequence may determine the fate of a species. Any advantage, no matter how small, will turn the scale of life in favor of its possessor and his progeny. "Battle within battle," says a famous naturalist, "must be continually recurring, with varying success. Yet in the long run the forces are so nicely balanced that the face of Nature remains for a long time uniform, though assuredly the merest trifle would give the victory to one organic being over another."

72. Artificial selection.—It has been long known that the nature of a herd or race of animals can be materially altered by a conscious selection on the part of man of these individuals which are to become parents. To "weed out" a herd artificially is to improve its blood. To select for reproduction the swiftest horses, the best milk cows, the most intelligent dogs, is to raise the standard of the herd or race in each of these respects by the simple action of heredity. Artificial selection has been called the "magician's wand," by which the breeder can summon up whatever animal form he will. If the parentage is chosen to a definite end, the process of heredity will develop the form

desired by a force as unchanging as that by which a stream turns a mill.

From the wild animals about him man has developed the domestic animals which he finds useful. The dog which man trains to care for his sheep is developed by selection from the most tractable progeny of the wolf which once devoured his flocks. By the process of artificial selection those individuals that are not useful to man or pleasing to his fancy have been destroyed, and those which contribute to his pleasure or welfare have been preserved and allowed to reproduce their kind. The various fancy breeds of pigeons—the carriers, pouters, tumblers, ruff-necks, and fan-tails—are all the descendants of the wild dove of Europe (*Columba livia*). These breeds or races or varieties have been produced by artificial selection. So it is with the various breeds of cattle and of hogs and of horses and dogs.

In this artificial selection new variations are more rapidly produced than in Nature by means of intercrossing different races, and by a more rapid weeding out of unfavorable—that is, of undesirable—variations. The rapid production of variations and the careful preservation of the desirable ones and rigid destruction of undesirable ones are the means by which many races of domestic animals are produced. This is artificial selection.

73. Dependence of species on species.—There was introduced into California from Australia, on young orange trees, a few years ago, an insect pest called the cottony cushion scale (*Icerya purchasi*). This pest increased in numbers with extraordinary rapidity, and in four or five years threatened to destroy completely the great orange orchards of California. Artificial remedies were of little avail. Finally, an entomologist was sent to Australia to find out if this scale insect had not some special natural enemy in its native country. It was found that in Australia a certain species of lady-bird beetle attacked and fed on the cottony

cushion scales and kept them in check. Some of these lady-birds (*Vedalia cardinalis*) were brought to California and released in a scale-infested orchard. The lady-birds, having plenty of food, thrived and produced many young. Soon the lady-birds were in such numbers that numbers of them could be distributed to other orchards. In two or three years the *Vedalias* had become so numerous and widely distributed that the cottony cushion scales began to diminish perceptibly, and soon the pest was nearly wiped out. But with the disappearance of the scales came also a disappearance of the lady-birds, and it was then discovered that the *Vedalias* fed only on cottony cushion scales and could not live where the scales were not. So now, in order to have a stock of *Vedalias* on hand in California it is necessary to keep protected some colonies of the cottony cushion scale to serve as food. Of course, with the disappearance of the predaceous lady-birds the scale began to increase again in various parts of the State, but with the sending of *Vedalias* to these localities the scale was again crushed. How close is the interdependence of these two species!

Similar relations can be traced in every group of animals. When the salmon cease to run in the Sacramento River in California the otter which feeds on them takes, it is said, to robbing the poultry-yards; and the bear, which also feeds on fish, strikes out for other game, taking fruit or chickens or bee-hives, whatever he may find.

CHAPTER VIII

ADAPTATIONS

74. Origin of adaptations.—The strife for place in the crowd of animals makes it necessary for each one to adjust itself to the place it holds. As the individual becomes fitted to its condition, so must the species as a whole. The species is therefore made up of individuals that are fitted or may become fitted for the conditions of life. As the stress of existence becomes more severe, the individuals fit to continue the species are chosen more closely. This choice is the automatic work of the conditions of life, but it is none the less effective in its operations, and in the course of centuries it becomes unerring. When conditions change, the perfection of adaptation in a species may be the cause of its extinction. If the need of a special fitness can not be met immediately, the species will disappear. For example, the native sheep of England have developed a long wool fitted to protect them in a cool, damp climate. Such sheep transferred to Cuba died in a short time, leaving no descendants. The warm fleece, so useful in England, rendered them wholly unfit for survival in the tropics. It is one advantage of man, as compared with other forms of life, that so many of his adaptations are external to his structure, and can be cast aside when necessity arises.

75. Classification of adaptations.—The various forms of adaptations may be roughly divided into five classes, as follows: (*a*) food securing, (*b*) self-protection, (*c*) rivalry, (*d*) defense of young, (*e*) surroundings.

The few examples which are given under each class,

some of them striking, some not especially so, are mostly chosen from the vertebrates and from the insects, because these two groups of animals are the groups with which beginning students of zoölogy are likely to be familiar, and the adaptations referred to are therefore most likely to be best appreciated. Quite as good and obvious examples could be selected from any other groups of animals. The student

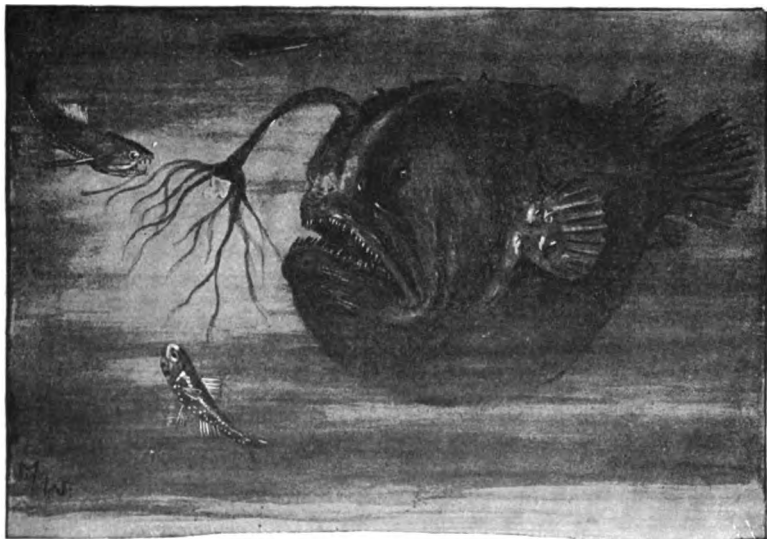


FIG. 54.—The deep-sea angler (*Corynolophus reinhardtii*), which has a dorsal spine modified to be a luminous "fishing rod and lure," attracting lantern-fishes (*Echiotoma* and *Ethophora*). An extraordinary adaptation for securing food. (The angler is drawn after a figure of LÖTKEN'S.)

will find good practice in trying to discover examples shown by the animals with which he may be familiar. That all or any part of the body structure of any animal can be called with truth an example of adaptation is plain from what we know of how the various organs of the animal body have come to exist. But by giving special attention to such adaptations as are plainly obvious, beginning stu-

dents may be put in the way of independent observation along an extremely interesting and attractive line of zoölogical study.

• 76. **Adaptations for securing food.**—For the purpose of capture of their prey, some carnivorous animals are provided with strong claws, sharp teeth, hooked beaks, and other structures familiar to us in the lion, tiger, dog, cat, owl, and eagle. Insect-eating mammals have contrivances especially

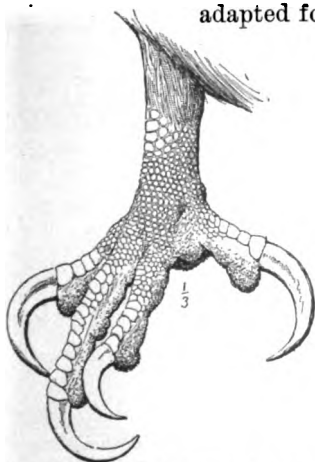


FIG. 56.—Foot of the bald eagle, showing claws for seizing its prey. (CHAPMAN.)



FIG. 55.—The brown pelican, showing gular sac, which it uses in catching and holding fishes that form its food.

adapted for the catching of insects. The ant-eater, for example, has a curious, long sticky tongue which it thrusts forth from its cylindrical snout deep into the recesses of the ant-hill, bringing it out with its sticky surface covered with ants. Animals which feed on nuts are fitted with strong teeth or beaks for cracking them. Similar teeth are found in those fishes which feed on crabs, snails, or sea-urchins. Those mammals like the horse and cow, that feed on plants, have usually

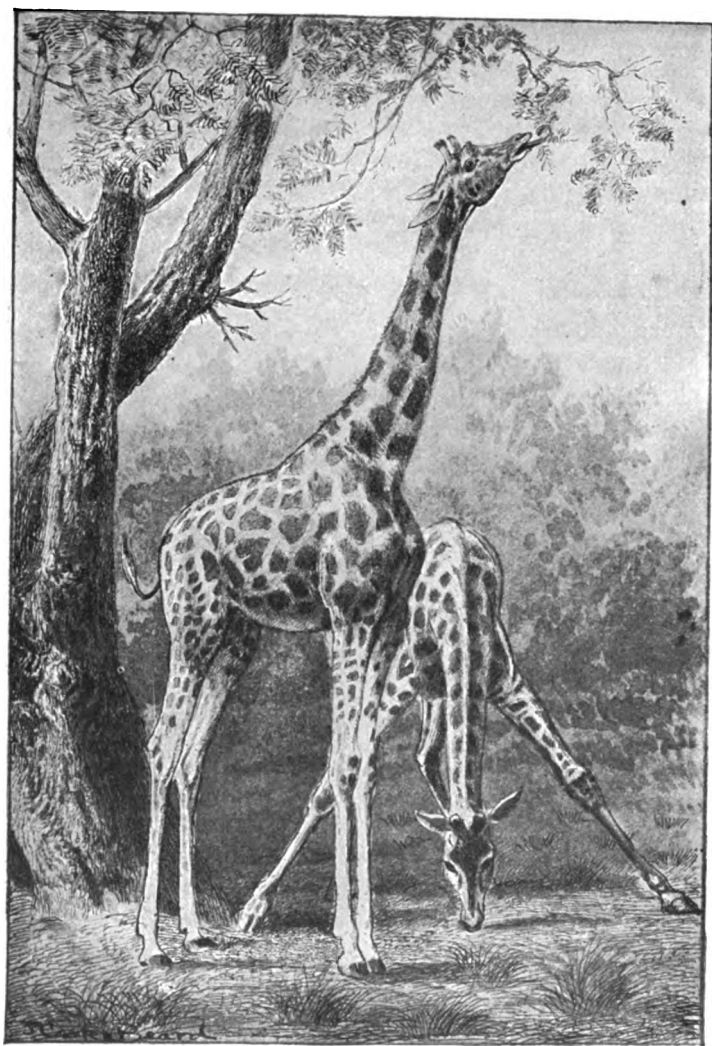


FIG. 57.—Giraffes feeding.

broad chisel-like incisor teeth for cutting off the foliage, and teeth of very similar form are developed in the different groups of plant-eating fishes. Molar teeth are found when it

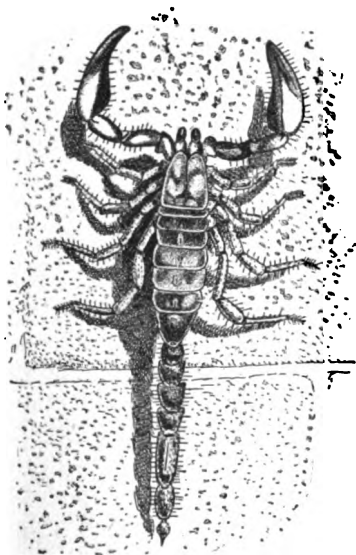


FIG. 58.—Scorpion, showing the special development of certain mouth parts (the maxillary palpi) as pincer-like organs for grasping prey. At the posterior tip of the body is the poisonous sting.



FIG. 59.—Head of mosquito (female), showing the piercing needle-like mouth parts which compose the "bill."

is necessary that the food should be crushed or chewed, and the sharp canine teeth go with a flesh diet. The long neck of the giraffe (Fig. 57) enables it to browse on the foliage of trees.

Insects like the leaf-beetles and the grasshoppers, that feed on the foliage of plants, have a pair of jaws, broad but



FIG. 60.—The praying-horse (*Mantis*) with fore legs developed as grasping organs.

sharply edged, for cutting off bits of leaves and stems. Those which take only liquid food, as the butterflies and sucking-bugs, have their mouth parts modified to form a slender, hollow sucking beak or proboscis, which can be



FIG. 61.—Acorns put into bark of tree by the Californian woodpecker (*Melanerpes formicivorus bairdii*). —From photograph, Stanford University, California.

thrust into a flower nectary, or into the green tissue of plants or the flesh of animals, to suck up nectar or plant sap or blood, depending on the special food habits of the insect. The honey-bee has a very complicated equipment of mouth parts fitted for taking either solid food like pollen, or liquid food like the nectar of flowers. The mosquito has a "bill" (Fig. 59) composed of six sharp, slender needles for piercing and lacerating the flesh, and a long tubular under lip through which the blood can flow into the mouth. Some predaceous insects, as the praying-horse (Fig. 60), have their fore legs developed into formidable grasping organs for seizing and holding their prey.

77. Adaptation for self-defense.—For self-protection, carnivorous animals use the same weapons to defend themselves which serve to secure their prey; but these as well as

other animals may protect themselves in other fashions. Most of the hoofed animals are provided with horns, struc-



FIG. 62.—Section of bark of live oak tree with acorns placed in it by the Californian woodpecker (*Melanerpes formicivorus bairdii*).—From photograph, Stanford University, California.

tures useless in procuring food but often of great effectiveness as weapons of defense. To the category of structures useful for self-defense belong the many peculiarities of coloration known as “recognition marks.” These are marks,

not otherwise useful, which are supposed to enable members of any one species to recognize their own kind among the mass of animal life. To this category belongs the



FIG. 63.—Centiped. The foremost pair of legs is modified to be a pair of seizing and stinging organs. An adaptation for self-defense and for securing food.

black tip of the weasel's tail, which remains the same whatever the changes in the outer fur. Another example is seen in the white outer feathers of the tail of the meadow-lark as well as in certain sparrows and warblers. The white on the skunk's back and tail serves the same purpose and also as a warning. It is to the skunk's advantage not to be hidden, for to be seen in the crowd of animals is to be avoided by them. The songs of birds and the calls of various creatures serve also as recognition marks. Each species knows and heeds its own characteristic song or cry, and it is a source of mutual protection. The fur-seal pup knows its mother's call, even though ten thousand other mothers are calling on the rookery.

The ways in which animals make themselves disagreeable or dangerous to their captors are almost as varied as the animals themselves. Besides the teeth, claws, and horns of ordinary attack and defense, we find among the mammals many special structures or contrivances which serve for defense through making their possession unpleasant. The scent glands of the skunk and its relatives are noticed above. The porcupine has the bristles in its fur specialized as quills, barbed and detachable. These quills fill the mouth of an attacking fox or wolf, and serve well the purpose of defense. The hedgehog of Europe, an animal of different nature, being related rather to the mole than to

the squirrel, has a similar armature of quills. The armadillo of the tropics has movable shields, and when it withdraws its

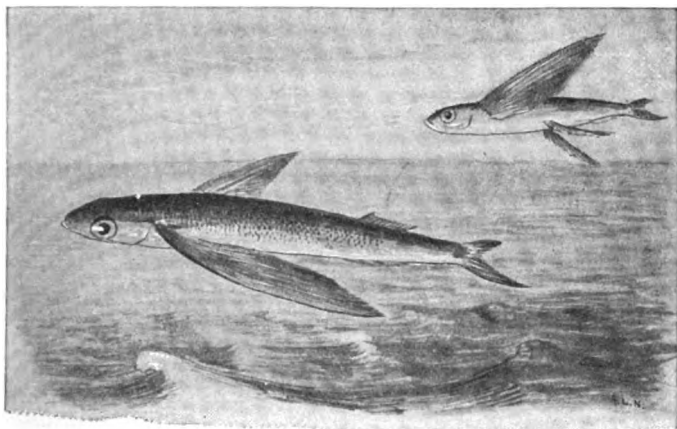


FIG. 64.—Flying fishes. (The upper one a species of *Cypselurus*, the lower of *Exocoetidae*.) These fishes escape from their enemies by leaping into the air and sailing or "flying" long distances.

head (which is also defended by a bony shield) it is as well protected as a turtle.

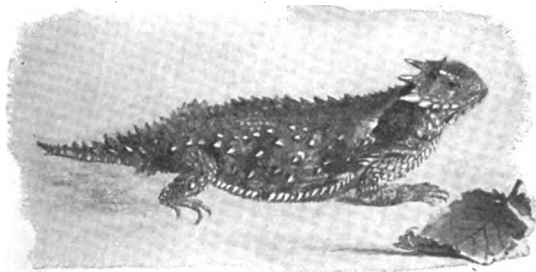


FIG. 65.—The horned toad (*Phrynosoma blainvilliei*). The spiny covering repels many enemies.

Special organs for defense of this nature are rare among birds, but numerous among reptiles. The turtles are all

protected by bony shields, and some of them, the box-turtles, may close their shields almost hermetically. The snakes broaden their heads, swell their necks, or show their forked tongues to frighten their enemies. Some of them

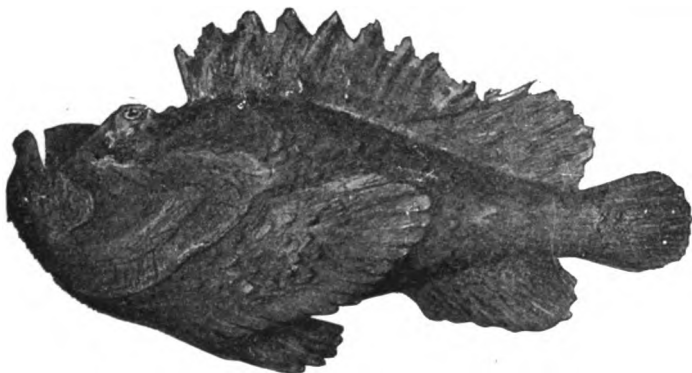


FIG. 66.—Nokee or poisonous scorpion-fish (*Emmydrichtys vulcanus*) with poisonous spines, from Tahiti.

are further armed with fangs connected with a venom gland, so that to most animals their bite is deadly. Besides its fangs the rattlesnake has a rattle on the tail made up of a

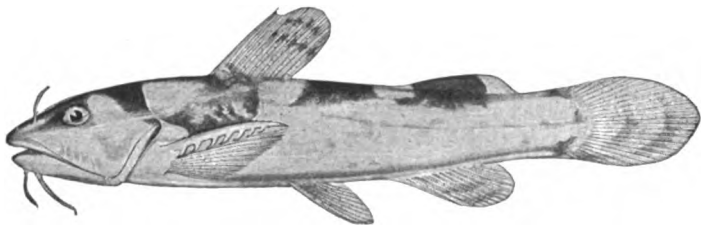


FIG. 67.—Mad tom (*Schilbeodes furiosus*) with poisoned pectoral spine.

succession of bony clappers, modified vertebræ, and scales, by which intruders are warned of their presence. This sharp and insistent buzz is a warning to animals of other species and a recognition signal to those of its own kind.

Even the fishes have many modes of self-defense through giving pain or injury to those who would swallow them. The cat-fishes or horned pouts when attacked set immovably the sharp spine of the pectoral fin, inflicting a jagged wound. Pelicans who have swallowed a cat-fish have been known to die of the wounds inflicted by the fish's spine. In the group of scorpion-fishes and toad-fishes are certain genera in which these spines are provided with poison glands. These may inflict very severe wounds to other fishes, or even to birds or man. One of this group of poison-fishes is the nokee (*Emmydrichthys*, Fig. 66). A group of small fresh-water cat-fishes, known as the mad toms (Fig. 67), have also a poison gland attached to the pectoral spine, and its sting is most exasperating, like the sting of a wasp. The sting-rays (Fig. 68) of many species have a strong, jagged spine on the tail, covered with slime, and armed with broad saw-like teeth. This inflicts a dangerous wound, not through the presence of specific venom, but from the danger of blood poisoning arising from the slime, and the ragged or unclean cut.

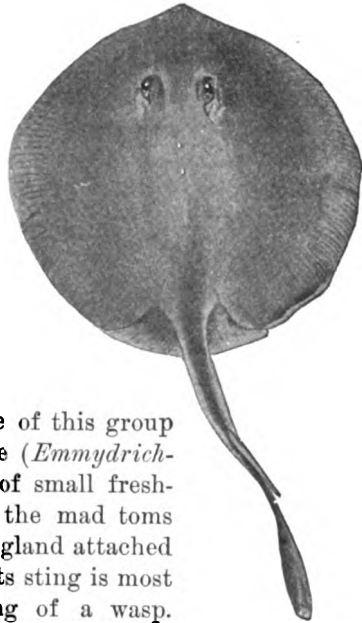


FIG. 68.—A sting-ray
(*Trolophus goodeti*),
from Panama.

Many fishes are defended by a coat of mail or a coat of sharp thorns. The globe-fishes and porcupine-fishes (Fig. 69) are for the most part defended by spines, but their instinct to swallow air gives them an additional safeguard. When one of these fishes is disturbed it rises to the surface,

gulps air until its capacious stomach is filled, and then floats belly upward on the surface. It is thus protected from other fishes, though easily taken by man. The torpedo, electric eel, electric cat-fish, and star-gazer, surprise and

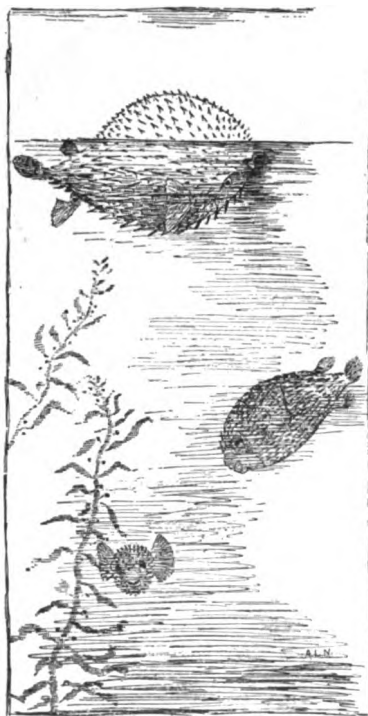


FIG. 69.—Porcupine-fish (*Diodon hystrix*), the lower ones swimming normally, the upper one floating belly upward, with inflated stomach.—Drawn from specimens from the Florida Keys.

stagger their captors by means of electric shocks. In the torpedo or electric ray (Fig. 70), found on the sandy shores of all warm seas, on either side of the head is a large honeycomb-like structure which yields a strong electric shock whenever the live fish is touched. This shock is felt severely if the fish be stabbed with a knife or metallic spear. The electric eel of the rivers of Paraguay and southern Brazil is said to give severe shocks to herds of wild horses driven through the streams, and similar accounts are given of the electric cat-fish of the Nile.

Among the insects, the possession of stings is not uncommon. The wasps and bees are fa-

miliar examples of stinging insects, but many other kinds, less familiar, are similarly protected. All insects have their bodies covered with a coat of armor, composed of a horny substance called chitin. In some cases this chitin-

ous coat is very thick and serves to protect them effectually. This is especially true of the beetles. Some insects are inedible (as mentioned in Chapter XII), and are conspicuously colored so as to be readily recognized by insectivorous birds. The birds, knowing by experience that these insects are ill-tasting, avoid them. Others are effectively concealed from their enemies by their close resemblance in color and marking to their surroundings. These protective resemblances are discussed in Chapter XII.

78. Adaptation for rivalry.

—In questions of attack and defense, the need of meeting animals of their own kind as well as animals of other races must be considered. In struggles of species with those of their own kind, the term rivalry may be applied. Actual warfare is confined mainly to males in the breeding season and to polygamous animals. Among those in which the male mates with many females, he must struggle with other males for their possession. In all the groups of vertebrates the sexes are about equal in numbers. Where mating exists, either for the season or for life, this condition does not involve serious struggle or destructive rivalry.

Among monogamous birds, or those which pair, the male courts the female of his choice by song and by display

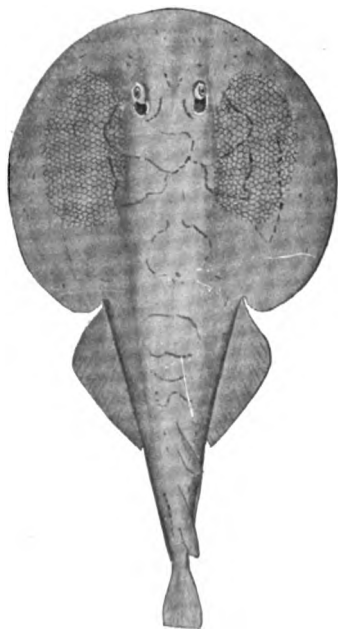


FIG. 70.—Torpedo or electric ray (*Narcine brasiliensis*), showing electric cells.



Fig. 71.—A fur seal (*Callorhinus alascanus*) family on the Voestochl rookery, St. Paul Island. The largest seal, at left end of group, is the male.—Photograph by D. W. THOMPSON and A. W. MAHRETT

of his bright feathers. The female consents to be chosen by the one which pleases her. It is believed that the handsomest, most vivacious, and most musical males are the ones most successful in such courtship. With polygamous animals there is intense rivalry among the males in the mating season, which in almost all species is in the spring. The strongest males survive and reproduce their strength. The most notable adaptation is seen in the superior size of teeth, horns, mane, or spurs. Among the polygamous fur seals (Fig. 71) and sea lions the male is about four times

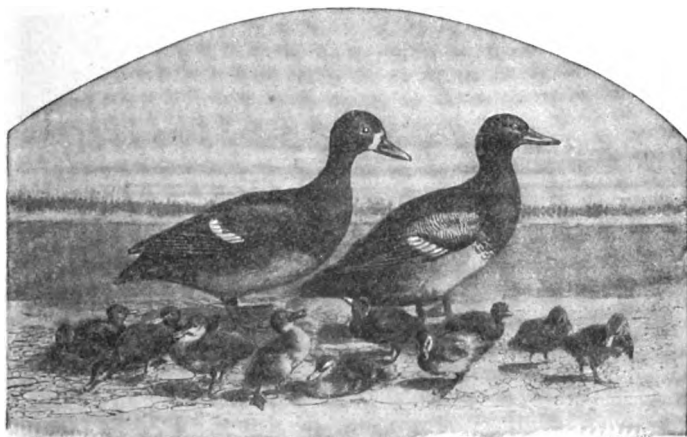


FIG. 72.—A wild duck (*Aythya*) family. Male, female, and precocial young.

the size of the female. In the polygamous family of deer, buffalo, and the domestic cattle and sheep, the male is larger and more powerfully armed than the female. In the polygamous group to which the hen, turkey, and peacock belong the males possess the display of plumage, and the structures adapted for fighting, with the will to use them.

79. Adaptations for the defense of the young.—The protection of the young is the source of many adaptive structures as well as of the instincts by which such structures are

utilized. In general, those animals are highest in development, with best means of holding their own in the struggle



FIG. 73.—The altricial nestlings of the Blue jay (*Cyanocitta cristata*).

for life, that take best care of their young. The homes of animals are elsewhere specially discussed (see Chapter

XV), but those instincts which lead to home-building may all be regarded as useful adaptations in preserving the young. Among the lower or more coarsely organized



FIG. 74.—Kangaroo (*Macropus rufus*) with young in pouch.

birds, such as the chicken, the duck, and the auk, as with the reptiles, the young animal is hatched with well-developed



FIG. 75.—Egg-case of California barn-door skate (*Raja binoculata*) cut open to show young inside. (Young issues naturally at one end of the case.)

muscular system and sense organs, and is capable of running about, and, to some extent, of feeding itself. Birds of this type are known as *præcocial* (Fig. 72), while the name *altricial* (Fig. 73) is applied to the more highly organized forms, such as the thrushes, doves, and song-birds generally. With these the young are hatched in a wholly helpless condition, with ineffective muscles, deficient senses, and dependent wholly upon the parent. The altricial condition demands the building of a nest, the establishment of a home, and the continued care of one or both of the parents.

The very lowest mammals known, the duck-bills (Monotremes) of Australia, lay large eggs in a strong shell like those of a turtle, and guard them with great jealousy. But with almost all mammals the egg is very small and without much food-yolk. The egg begins its development within the body. It is nourished by the blood of the mother, and after birth the young is cherished by her, and fed by milk secreted by specialized glands of the skin. All these features are adaptations tending toward the preservation of the young. In the division of mammals next lowest to the Monotremes—the kangaroo, opossum, etc.—the young are born in a very immature state and are at once seized by the mother and



FIG. 76.—Egg-case of the cockroach.

thrust into a pouch or fold of skin along the abdomen, where they are kept until they are able to take care of themselves (Fig. 74). This is an interesting and ingenious adaptation, but less specialized and less perfect an adaptation than the conditions found in ordinary mammals.

Among the insects, the special provisions for the protection and care of the eggs and the young are wide-spread and various. Some of those adaptations which take the special form of nests or "homes" will be described in a later chapter (see Chapter XV). The eggs of the common cockroach are laid in small packets inclosed in a firm wall

(Fig. 76). The eggs of the great water-bugs are carried on the back of the male (Fig. 77); and the spiders lay their eggs in a silken sac or cocoon, and some of the ground or



FIG. 77.—Giant water-bug (*Serpaphys*). Male carrying eggs on its back.

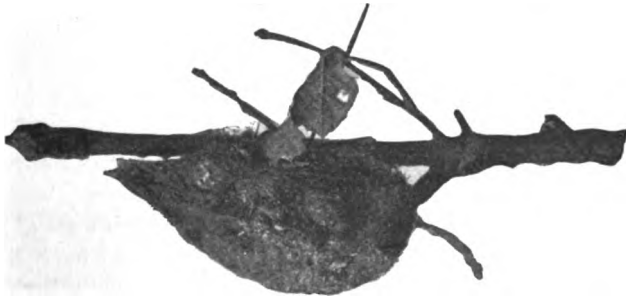


FIG. 78.—Cocoon inclosing the pupa of the great Ceanothus moth. Spun of silk by the larva before pupation.

running spiders (*Lycosidæ*) drag this egg-sac, attached to the tip of the abdomen, about with them. The young spiders when hatched live for some days inside this sac, feeding on each other! Many insects have long, sharp,

piercing ovipositors, by means of which the eggs are deposited in the ground or in the leaves or stems of green plants, or even in the hard wood of tree-trunks. Some of

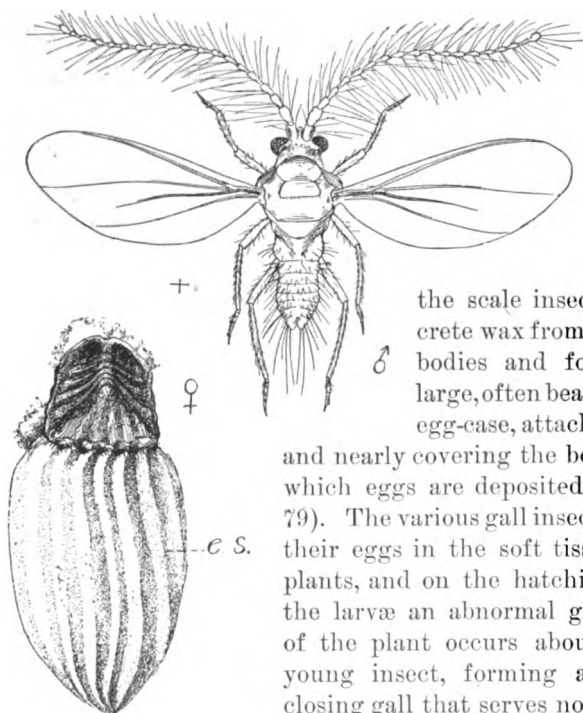


FIG. 79.—The cottony cushion scale insect (*Icerya purchasi*), from California. The male is winged, the female wingless and with a large waxen egg-sac (*e.s.*) attached to her body. (The lines at the left of each figure indicate the size of the insects.)

the scale insects secrete wax from their bodies and form a large, often beautiful egg-case, attached to and nearly covering the body in which eggs are deposited (Fig. 79). The various gall insects lay their eggs in the soft tissue of plants, and on the hatching of the larvæ an abnormal growth of the plant occurs about the young insect, forming an inclosing gall that serves not only to protect the insect within, but to furnish it with an abundance of plant-sap, its food. The young insect remains in the gall until it completes its development and growth, when it

gnaws its way out. Such insect galls are especially abundant on oak trees (Fig. 80). The care of the eggs and the young of the social insects, as the bees and ants, are described in Chapter IX.

80. **Adaptations concerned with surroundings in life.**—A large part of the life of the animal is a struggle with the environment itself; in this struggle only those that are adapted live and leave descendants fitted like themselves. The fur of mammals fits them to their surroundings. As the fur differs, so may the habits change. Some animals are active in winter; others, as the bear, hibernate, sleeping in caves or hollow trees or in burrows until conditions are favorable for their activity. Most snakes and lizards hibernate in cold weather. In the swamps of Louisiana,

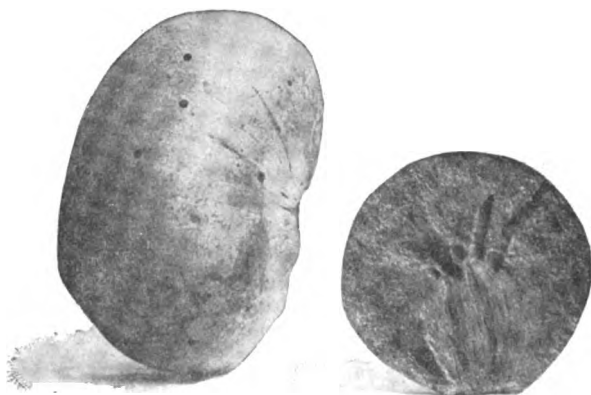


FIG. 80.—The giant gall of the white oak (California), made by the gall insect *Andricus californicus*. The gall at the right cut open to show tunnels made by the insects in escaping from the gall.—From photograph.

in winter, the bottom may often be seen covered with water snakes lying as inert as dead twigs. Usually, however, hibernation is accompanied by concealment. Some animals in hibernation may be frozen alive without apparent injury. The blackfish of the Alaska swamps, fed to dogs when frozen solid, has been known to revive in the heat of the dog's stomach and to wriggle out and escape. As animals resist heat and cold by adaptations of structure or habits, so may they resist dryness. Certain fishes hold reservoirs

of water above their gills, by means of which they can breathe during short excursions from the water. Still others (mud-fishes) retain the primitive lung-like structure of the swim-bladder, and are able to breathe air when, in the dry season, the water of the pools is reduced to mud.

Another series of adaptations is concerned with the places chosen by animals for their homes. The fishes that



FIG. 81.—Insect galls on leaf.

live in water have special organs for breathing under water (Fig. 82). Many of the South American monkeys have the tip of the tail adapted for clinging to limbs of trees or to the bodies of other monkeys of its own kind. The hooked claws of the bat hold on to rocks, the bricks of chimneys, or to the surface of hollow trees where the bat sleeps through the day. The tree-frogs (Fig. 83) or tree-toads have the tips of the toes swollen, forming little pads by which they cling to the bark of trees.

Among other adaptations relating to special surroundings or conditions of life are the great cheek pouches of the pocket gophers, which carry off the soil dug up by the large shovel-like feet when the gopher excavates its burrow.

Those insects which live underground, making burrows or tunnels in the soil, have their legs or other parts adapted for digging and burrowing. The mole cricket (Fig. 84) has its legs stout and short, with broad, shovel-like feet. Some water-beetles (Fig. 85) and water-bugs have one or more of the pairs of legs flattened and broad to serve as oars or paddles for swimming. The grasshoppers or locusts, who leap,

have their hind legs greatly enlarged and elongated, and provided with strong muscles, so as to make of them "leaping legs." The grubs

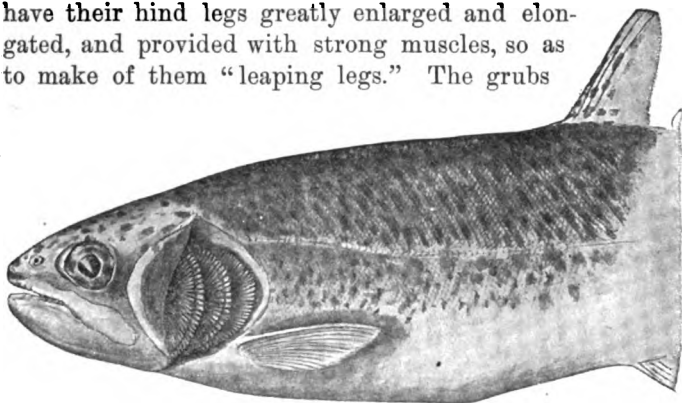


FIG. 82.—Head of rainbow trout (*Salmo irideus*) with gill cover bent back to show gills, the breathing organs.

or larvæ of beetles which live as "borers" in tree-trunks have mere rudiments of legs, or none at all (Fig. 86). They have great, strong, biting jaws for cutting away the hard wood. They move simply by wriggling along in their burrows or tunnels.

Insects that live in water either come up to the surface to breathe or take down air underneath their wings, or in some other way, or have gills for breathing the air which is mixed with the water. These gills are special adap-



FIG. 83.—Tree-toad (*Hyla regilla*).

tive structures which present a great variety of form and appearance. In the young of the May-flies they are delicate plate-like flaps projecting from the sides of the body. They are kept in constant motion, gently waving back and

forth in the water so as to maintain currents to bring fresh water in contact with them. Young mosquitoes (Fig. 87)

do not have gills, but come up to the surface to breathe. The larvæ, or wrigglers, breathe through a special



FIG. 84.—The mole cricket (*Gryllotalpa*), with fore feet modified for digging.



FIG. 85.—A water-beetle (*Hydrophilus*).

tube at the posterior tip of the body, while the pupæ have a pair of horn-like tubes on the back of the head end of the body.

81. **Degree of structural change in adaptations.**—While among the higher or vertebrate animals, especially the fishes and reptiles, most remarkable cases of adaptations occur, yet the structural changes are for the most part external, never seriously affecting the development of the internal organs other than the skeleton. The organization of these higher animals is much less plastic than among the invertebrates. In general, the higher the type the more persistent and unchangeable are those structures not immediately exposed



FIG. 86.—Wood-boring beetle larva (*Prionus*).

to the influence of the struggle for existence. It is thus the outside of an animal that tells where its ancestors have lived. The inside, suffering little change, whatever the surroundings, tells the real nature of the animal.

82. **Vestigial organs.**—In general, all the peculiarities of animal structure find their explanation in some need of adaptation. When this need ceases, the structure itself tends to disappear or else to serve some other need. In the bodies of most animals there are certain incomplete or rudimentary organs or structures which serve no distinct useful purpose. They are structures which, in the ancestors of the animals now possessing them, were fully developed functional organs, but which, because of a change in habits or conditions of living, are of no further need, and are gradually dying out. Such organs are called vestigial organs. Examples are the disused ear muscles of man, the vermiform appendix in man, which is the reduced and now useless anterior end of the large intestine. In the lower animals, the thumb or degenerate first finger of the bird with its two or three little quills serves as an example. So also the reduced and elevated hind toe of certain birds, the splint bones or rudimentary side toes of the horse, the rudimentary eyes of blind fishes, the minute barbel or beard of the horned dace or chub, and the rudimentary teeth of the right whales and sword-fish.

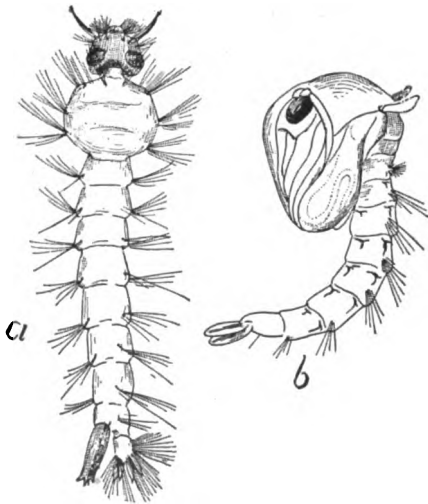


FIG. 87.—Young stages of the mosquito.
a, larva (wiggler); b, pupa.

Each of these vestigial organs tells a story of some past adaptation to conditions, one that is no longer needed in the life of the species. They have the same place in the study of animals that silent letters have in the study of words. For example, in our word knight the *k* and *gh* are no longer sounded; but our ancestors used them both, as the Germans do to-day in their cognate word *Knecht*. So with the French word *temps*, which means time, in which both *p* and *s* are silent. The Romans, from whom the French took this word, needed all its letters, for they spelled and pronounced it *tempus*. In general, every silent letter in every word was once sounded. In like manner, every vestigial structure was once in use and helpful or necessary to the life of the animal which possessed it.



Horns of two male deer interlocked while fighting. Permission of G. O. SHIELDS, publisher of *Recreation*.

CHAPTER IX

ANIMAL COMMUNITIES AND SOCIAL LIFE

83. **Man not the only social animal.**—Man is commonly called the social animal, but he is not the only one to which this term may be applied. There are many others which possess a social or communal life. A moment's thought brings to mind the familiar facts of the communal life of the honey-bee and of the ants. And there are many other kinds of animals, not so well known to us, that live in communities or colonies, and live a life which in greater or less degree is communal or social. In this connection we may use the term communal for the life of those animals in which the division of labor is such that the individual is dependent for its continual existence on the community as a whole. The term social life would refer to a lower degree of mutual aid and mutual dependence.

84. **The honey-bee.**—Honey-bees live together, as we know, in large communities. We are accustomed to think of honey-bees as the inhabitants of bee-hives, but there were bees before there were hives. The "bee-tree" is familiar to many of us. The bees, in Nature, make their home in the hollow of some dead or decaying tree-trunk, and carry on there all the industries which characterize the busy communities in the hives. A honey-bee community comprises three kinds of individuals (Fig. 88)—namely, a fertile female or queen, numerous males or drones, and many infertile females or workers. These three kinds of individuals differ in external appearance sufficiently to be readily recognizable. The workers are

smaller than the queens and drones, and the last two differ in the shape of the abdomen, or hind body, the abdomen of the queen being longer and more slender than that of the

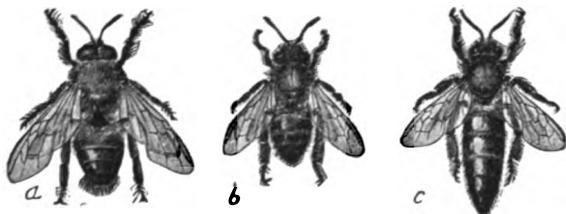


FIG. 88.—Honey-bee. *a*, drone or male; *b*, worker or infertile female; *c*, queen or fertile female.

male or drone. In a single community there is one queen, a few hundred drones, and ten to thirty thousand workers. The number of drones and workers varies at different times of the year, being smallest in winter. Each kind of individual has certain work or business to do for the whole community. The queen lays all the eggs from which new bees are born; that is, she is the mother of the entire community. The drones or males have simply to act as royal consorts; upon them depends the fertilization of the eggs. The workers undertake all the food-getting, the care of the young bees, the comb-building, the honey-making—all the industries with which we are more or less familiar that are carried on in the hive. And all the work done by the workers is strictly work for the whole community; in no case does the worker bee work for itself alone; it works for itself only in so far as it is a member of the community.

How varied and elaborately perfected these industries are may be perceived from a brief account of the life history of a bee community. The interior of the hollow in the bee-tree or of the hive is filled with "comb"—that is, with wax molded into hexagonal cells and supports for these cells. The molding of these thousands of symmet-

rical cells is accomplished by the workers by means of their specially modified trowel-like mandibles or jaws. The wax itself, of which the cells are made, comes from the bodies of the workers in the form of small liquid drops which exude from the skin on the under side of the abdomen or hinder body rings. These droplets run together, harden and become flattened, and are removed from the wax plates, as the peculiarly modified parts of the skin which produce the wax are called, by means of the hind legs, which are furnished with scissor-like contrivances for cutting off the wax (Fig. 89). In certain of the cells are stored the pollen and honey, which serve as food for the community. The pollen is gathered by the workers from certain favorite flowers and is carried by them from the flowers to the hive in the "pollen baskets," the slightly concave outer surfaces of one of the segments of the broadened and flattened hind legs. This concave surface is lined on each margin with a row of incurved stiff hairs which hold the pollen mass securely in place (Fig. 89). The "honey" is the nectar of flowers which has been sucked up by the workers by means of their elaborate lapping and sucking mouth parts and swallowed into a sort of honey-sac or stomach, then brought to the hive and regurgitated into the cells. This nectar is at first too watery to be good honey, so the bees have to evaporate some of this water. Many of the workers gather above the cells containing

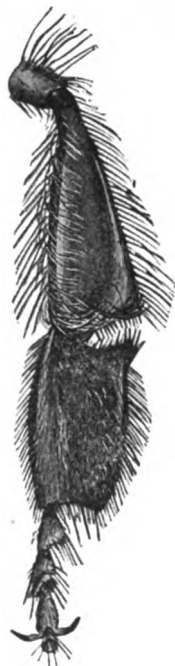


FIG. 89.—Posterior leg of worker honey-bee. The concave surface of the upper large joint with the marginal hairs is the pollen basket; the wax shears are the cutting surfaces of the angle between the two large segments of the leg.

nectar, and buzz—that is, vibrate their wings violently. This creates currents of air which pass over the exposed nectar and increase the evaporation of the water. The violent buzzing raises the temperature of the bees' bodies, and this warmth given off to the air also helps make evaporation more rapid. In addition to bringing in food the workers also bring in, when necessary, "propolis," or the resinous gum of certain trees, which they use in repairing the hive, as closing up cracks and crevices in it.

In many of the cells there will be found, not pollen or honey, but the eggs or the young bees in larval or pupal condition (Fig. 90).

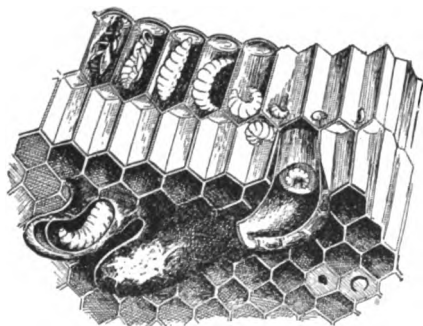


FIG. 90.—Cells containing eggs, larvæ, and pupæ of the honey-bee. The lower large, irregular cells are queen cells.—After BENTON.

The queen moves about through the hive, laying eggs. She deposits only one egg in a cell. In three days the egg hatches, and the young bee appears as a helpless, soft, white, footless grub or larva. It is cared for by certain of the workers, that may be

called nurses. These nurses do not differ structurally from the other workers, but they have the special duty of caring for the helpless young bees. They do not go out for pollen or honey, but stay in the hive. They are usually the new bees—i. e., the youngest or most recently added workers. After they act as nurses for a week or so they take their places with the food-gathering workers, and other new bees act as nurses. The nurses feed the young or larval bees at first with a highly nutritious food called bee-jelly, which the nurses make in their stomach, and regurgitate for the larvæ. After the larvæ are two or three days old

they are fed with pollen and honey. Finally, a small mass of food is put into the cell, and the cell is "capped" or covered with wax. The larva, after eating all the food, in two or three days more changes into a pupa, which lies quiescent without eating for thirteen days, when it changes into a full-grown bee. The new bee breaks open the cap of the cell with its jaws, and comes out into the hive, ready to take up its share of the work for the community. In a few cases, however, the life history is different. The nurses will tear down several cells around some single one, and enlarge this inner one into a great irregular vase-shaped cell. When the egg hatches, the grub or larva is fed bee-jelly as long as it remains a larva, never being given ordinary pollen and honey at all. This larva finally pupates, and there issues from the pupa not a worker or drone bee, but a new queen. The egg from which the queen is produced is the same as the other eggs, but the worker nurses by feeding the larva only the highly nutritious bee-jelly make it certain that the new bee shall become a queen instead of a worker. It is also to be noted that the male bees or drones are hatched from eggs that are not fertilized, the queen having it in her power to lay either fertilized or unfertilized eggs. From the fertilized eggs hatch larvæ which develop into queens or workers, depending on the manner of their nourishment; from the unfertilized eggs hatch the males.

When several queens appear there is much excitement in the community. Each community has normally a single one, so that when additional queens appear some rearrangement is necessary. This rearrangement comes about first by fighting among the queens until only one of the new queens is left alive. Then the old or mother queen issues from the hive or tree followed by many of the workers. She and her followers fly away together, finally alighting on some tree branch and massing there in a dense swarm. This is the familiar phenomenon of "swarming." The

swarm finally finds a new hollow tree, or in the case of the hive-bee (Fig. 91) the swarm is put into a new hive, where the bees build cells, gather food, produce young, and thus



FIG. 91.—Hiving a swarm of honey-bees. Photograph by S. J. HUNTER.

found a new community. This swarming is simply an emigration, which results in the wider distribution and in the increase of the number of the species. It is a peculiar but effective mode of distributing and perpetuating the species.

There are many other interesting and suggestive things which might be told of the life in a bee community: how the community protects itself from the dangers of starvation when food is scarce or winter comes on by killing the useless drones and the immature bees in egg and larval stage; how the instinct of home-finding has been so highly developed that the worker bees go miles away for honey and nectar, flying with unerring accuracy back to the hive; of the extraordinarily nice structural modifications which adapt the bee so perfectly for its complex and varied businesses; and of the tireless persistence of the workers until

they fall exhausted and dying in the performance of their duties. The community, it is important to note, is a persistent or continuous one. The workers do not live long, the spring broods usually not over two or three months, and the fall broods not more than six or eight months; but new ones are hatching while the old ones are dying, and the community as a whole always persists. The queen may live several years, perhaps as many as five.* She lays about one million eggs a year.

85. **The ants.**—There are many species of ants, two thousand or more, and all of them live in communities and show a truly communal life. There is much variety of habit in the lives of different kinds of ants, and the degree in which the communal or social life is specialized or elaborated varies much. But certain general conditions prevail in the life of all the different kinds of individuals—

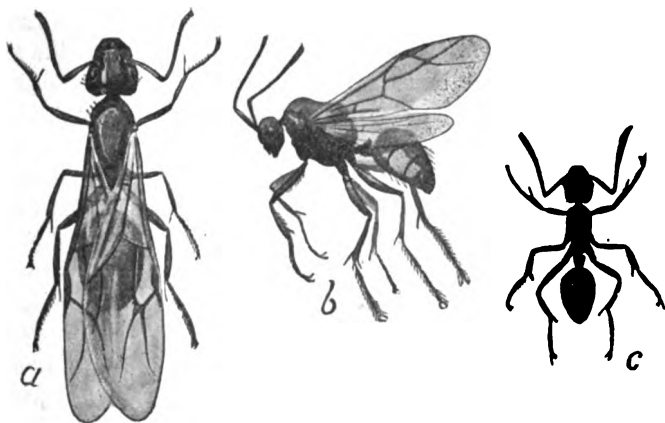


FIG. 92.—Female (a), male (b), and worker (c) of an ant (*Camponotus* sp.).

sexually developed males and females that possess wings, and sexually undeveloped workers that are wingless (Fig. 92). In some kinds the workers show structural differ-

* A queen bee has been kept alive for fifteen years.

ences among themselves, being divided into small workers, large workers, and soldiers. The workers are not, as with the bees, all infertile females, but they are both male and female, both being infertile. Although the life of the ant communities is much less familiar and fully known than that of the bees, it is even more remarkable in its specializations and elaborateness. The ant home, or nest, or formicary, is, with most species, a very elaborate underground, many-storied labyrinth of galleries and chambers. Certain rooms are used for the storage of food; certain others as "nurseries" for the reception and care of the young; and others as stables for the ants' cattle, certain plant-lice or scale-insects which are sometimes collected and cared for by the ants. The food of ants comprises many kinds of vegetable and animal substances, but the favorite food, or "national dish," as it has been called, is a sweet fluid which is produced by certain small insects, the plant-lice (Aphidæ) and scale-insects (Coccidæ). These insects live on the sap of plants; rose-bushes are especially favored with their presence. The worker ants (and we rarely see any ants but the wingless workers, the winged males and females appearing out of the nest only at mating time) find these honey-secreting insects, and gently touch or stroke them with their feelers (antennæ), when the plant-lice allow tiny drops of the honey to issue from the body, which are eagerly drunk by the ants. It is manifestly to the advantage of the ants that the plant-lice should thrive; but they are soft-bodied, defenseless insects, and readily fall a prey to the wandering predaceous insects like the lady-birds and aphid lions. So the ants often guard small groups of plant-lice, attacking, and driving away the would-be ravagers. When the branch on which the plant-lice are gets withered and dry, the ants have been observed to carry the plant-lice carefully to a fresh, green branch. In the Mississippi Valley a certain kind of plant-louse lives on the roots of corn. Its eggs are deposited in the ground in the autumn and hatch

the following spring before the corn is planted. Now, the common little brown ant lives abundantly in the corn-fields, and is specially fond of the honey secreted by the corn-root plant-louse. So, when the plant-lice hatch in the spring before there are corn roots for them to feed on, the little brown ants with great solicitude carefully place the plant-lice on the roots of a certain kind of knotweed which grows in the field, and protect them until the corn germinates. Then the ants remove the plant-lice to the roots of the corn, their favorite food plant. In the arid lands of New Mexico and Arizona the ants rear their scale-insects on the roots of cactus. Other kinds of ants carry plant lice into their nests and provide them with food there. Because the ants obtain food from the plant-lice and take care of them, the plant-lice are not inaptly called the ants' cattle.

Like the honey-bees, the young ants are helpless little grubs or larvæ, and are cared for and fed by nurses. The so-called ants' eggs, little white, oval masses, which we often see being carried in the mouths of ants in and out of an ants' nest, are not eggs, but are the pupæ which are being brought out to enjoy the warmth and light of the sun or being taken back into the nest afterward.

In addition to the workers that build the nest and collect food and care for the plant-lice, there is in many species of ants a kind of individuals called soldiers. These are wingless, like the workers, and are also, like the workers, not capable of laying or of fertilizing eggs. It is the business of the soldiers, as their name suggests, to fight. They protect the community by attacking and driving away predaceous insects, especially other ants. The ants are among the most warlike of insects. The soldiers of a community of one species of ant often sally forth and attack a community of some other species. If successful in battle the workers of the victorious community take possession of the food stores of the conquered and carry

them to their own nest. Indeed, they go even further; they may make slaves of the conquered ants. There are numerous species of the so-called slave-making ants. The slave-makers carry into their own nest the eggs and larvæ and pupæ of the conquered community, and when these come to maturity they act as slaves of the victors—that is, they collect food, build additions to the nests, and care for the young of the slave-makers. This specialization goes so far in the case of some kinds of ants, like the robber-ant of South America (*Eciton*), that all of the *Eciton* workers have become soldiers, which no longer do any work for themselves. The whole community lives, therefore, wholly by pillage or by making slaves of other kinds of ants. There are four kinds of individuals in a robber-ant community—winged males, winged females, and small and large wingless soldiers. There are many more of the small soldiers than of the large, and some naturalists believe that the few latter, which are distinguished by heads and jaws of great size, act as officers. On the march the small soldiers are arranged in a long, narrow column, while the large soldiers are scattered along on either side of the column and appear to act as sentinels and directors of the army. The observations made by the famous Swiss students of ants, Huber and Forel, and by other naturalists, read like fairy tales, and yet are the well-attested and often reobserved actual phenomena of the extremely specialized communal and social life of these animals.

86. Other communal insects.—The termites or white ants (not true ants) are communal insects. Some species of termites in Africa live in great mounds of earth, often fifteen feet high. The community comprises hundreds of thousands of individuals, which are of eight kinds (Fig 93), viz., sexually active winged males, sexually active winged females, other fertile males and females which are wingless, wingless workers of both sexes not capable of reproduction, and wingless soldiers of both sexes also incapable of

reproduction. The production of new individuals is the sole business of the fertile males and females; the workers build the nest and collect food, and the soldiers protect the community from the attacks of marauding insects. The egg-laying queen grows to monstrous size, being sometimes

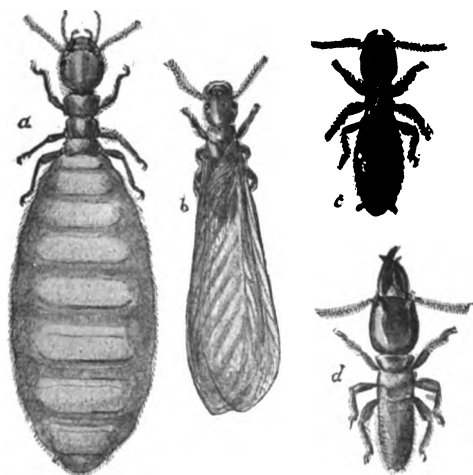


FIG. 93.—Termites. *a*, queen; *b*, male; *c*, worker; *d*, soldier.

five or six inches long, while the other individuals of the community are not more than half or three quarters of an inch long. The great size of the queen is due to the enormous number of eggs in her body.

The bumble-bees live in communities, but their social arrangements are very simple ones compared with those of the honey-bee. There is, in fact, among the bees a series of gradations from solitary to communal life. The interesting little green carpenter-bees live a truly solitary life. Each female bores out the pith from five or six inches of an elder branch or raspberry cane, and divides this space into a few cells by means of transverse partitions (Fig. 94). In each cell she lays an egg, and puts with it enough food—flower pollen—to last the grub or larva through its life.

She then waits in an upper cell of the nest until the young bees issue from their cells, when she leads them off, and each begins active life on its own account. The mining-



FIG. 94.—Nest of carpenter-bee.

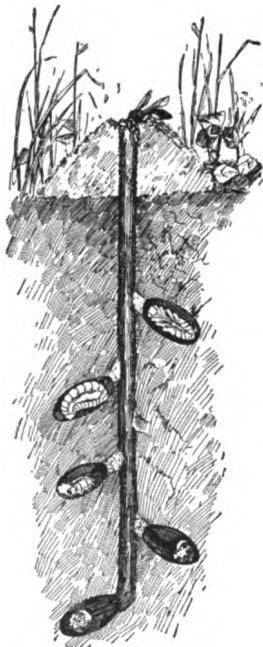


FIG. 95.—Nest of *Andrena*, the mining-bee.

bees (*Andrena*), which make little burrows (Fig. 95) in a clay bank, live in large colonies—that is, they make their nest burrows close together in the same clay bank, but each female makes her own burrow, lays her own eggs in it, furnishes it with food—a kind of paste of nectar and pollen—and takes no further care of her young. Nor has she at any time any special interest in her neighbors. But with the smaller mining-bees, belonging to the genus *Halictus*, several females unite in making a common burrow, after which each female makes side passages of her own, extend-

ing from the main or public entrance burrow. As a well-known entomologist has said, *Andrena* builds villages composed of individual homes, while *Halictus* makes cities composed of apartment houses. The bumble-bee (Fig. 96), however, establishes a real community with a truly communal life, although a very simple one. The few bumble-bees which we see in winter time are queens; all other bumble-bees die in the autumn. In the spring a queen selects some deserted nest of a field-mouse, or a hole in the ground, gathers pollen which she molds into a rather large irregular mass and puts into the hole, and lays a few eggs on the pollen mass. The young grubs or larvæ which soon hatch feed on the pollen, grow, pupate, and issue as workers—winged bees a little smaller than the queen. These workers bring more pollen, enlarge the nest, and make irregular cells in the pollen mass, in each of which the queen lays an egg. She gathers no more pollen, does no more work except that of egg-laying. From these new eggs are produced more workers, and so on until the community may come to be pretty large. Later in the summer males and females are produced and mate. With the approach of winter all the workers and males die, leaving only the fertilized females, the queens, to live through the winter and found new communities in the spring.

The social wasps show a communal life like that of the bumble-bees. The only yellow-jackets and hornets that live through the winter are fertilized females or queens.



FIG. 96.—Bumble-bees. *a*, worker; *b*, queen or fertile female.

When spring comes each queen builds a small nest suspended from a tree branch, and consisting of a small comb inclosed in a covering or envelope open at the lower end. The nest is composed of "wasp paper," made by chewing bits of weather-beaten wood taken from old fences or out-buildings. In each of the cells the queen lays an egg. She deposits in the cell a small mass of food, consisting of some chewed insects or spiders. From these eggs hatch grubs which eat the food prepared for them, grow, pupate, and issue as worker bees, winged and slightly smaller than the queen (Fig. 97). The workers enlarge the nest, adding more combs and making many cells, in each of which the queen lays an egg. The workers provision the cell with chewed insects, and other broods of workers are

rapidly hatched. The community grows in numbers and the nest grows in size until it comes to be the great ball-like oval mass which we know so well as a hornets' nest (Figs. 98 and 99), a thing to be left untouched. Sometimes the nest is built underground. When disturbed, they swarm out of the hole and fiercely attack any invading foe in sight. After a number of broods of workers has

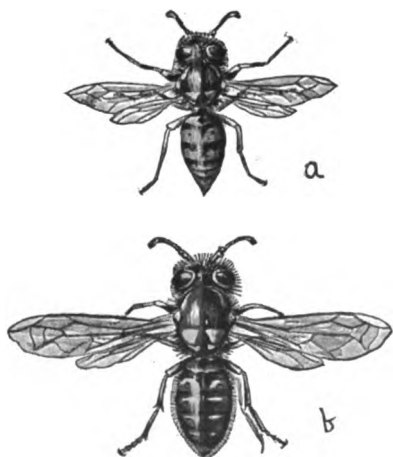


FIG. 97.—The yellow-jacket (*Vespa*), a social wasp. a, worker; b, queen.

been produced, broods of males and females appear and mating takes place. In the late fall the males and all of the many workers die, leaving only the new queens to live through the winter.

The bumble-bees and social wasps show an intermediate condition between the simply gregarious or neighborly



FIG. 98.—Nest of *Vespa*, a social wasp. From photograph.



FIG. 99.—Nest of *Vespa* opened to show combs within.

mining-bees and the highly developed, permanent honey-bee community. Naturalists believe that the highly organized communal life of the honey-bees and the ants is a development from some simple condition like that of the bumble-bees and social wasps, which in its turn has grown out of a still simpler, mere gregarious assembly of the individuals of one species. It is not difficult to see how such a development could in the course of a long time take place.

87. Gregariousness and mutual aid.—The simplest form of social life is shown among those kinds of animals in which many individuals of one species keep together, forming a great band or herd. In this case there is not much division of labor, and the safety of the individual is not wholly bound up in the fate of the herd. Such animals are

said to be *gregarious* in habit. The habit undoubtedly is advantageous in the mutual protection and aid afforded the individuals of the band. This mutual help in the case of many gregarious animals is of a very positive and obvious character. In other cases this gregariousness is reduced to a matter of slight or temporary convenience, possessing but little of the element of mutual aid. The great herds of reindeer in the north, and of the bison or buffalo which once ranged over the Western American plains, are examples of a gregariousness in which mutual protection from enemies, like wolves, seems to be the principal advantage gained. The bands of wolves which hunted the buffalo show the advantage of mutual help in aggression as well as in protection. In this banding together of wolves there is active co-operation among individuals to obtain a common food supply. What one wolf can not do—that is, tear down a buffalo from the edge of the herd—a dozen can do, and all are gainers by the operation. On the other hand, the vast assembling of sea-birds (Fig. 100) on certain ocean islands and rocks is a condition probably brought about rather by the special suitableness of a few places for safe breeding than from any special mutual aid afforded; still, these sea-birds undoubtedly combine to drive off attacking eagles and hawks. Eagles are usually considered to be strictly solitary in habit (the unit of solitariness being a pair, not an individual); but the description, by a Russian naturalist, of the hunting habits of the great white-tailed eagle (*Haliaeetus albicilla*) on the Russian steppes shows that this kind of eagle at least has adopted a gregarious habit, in which mutual help is plainly obvious. This naturalist once saw an eagle high in the air, circling slowly and widely in perfect silence. Suddenly the eagle screamed loudly. "Its cry was soon answered by another eagle, which approached it, and was followed by a third, a fourth, and so on, till nine or ten eagles came together and soon disappeared." The naturalist, following them, soon discovered them gathered

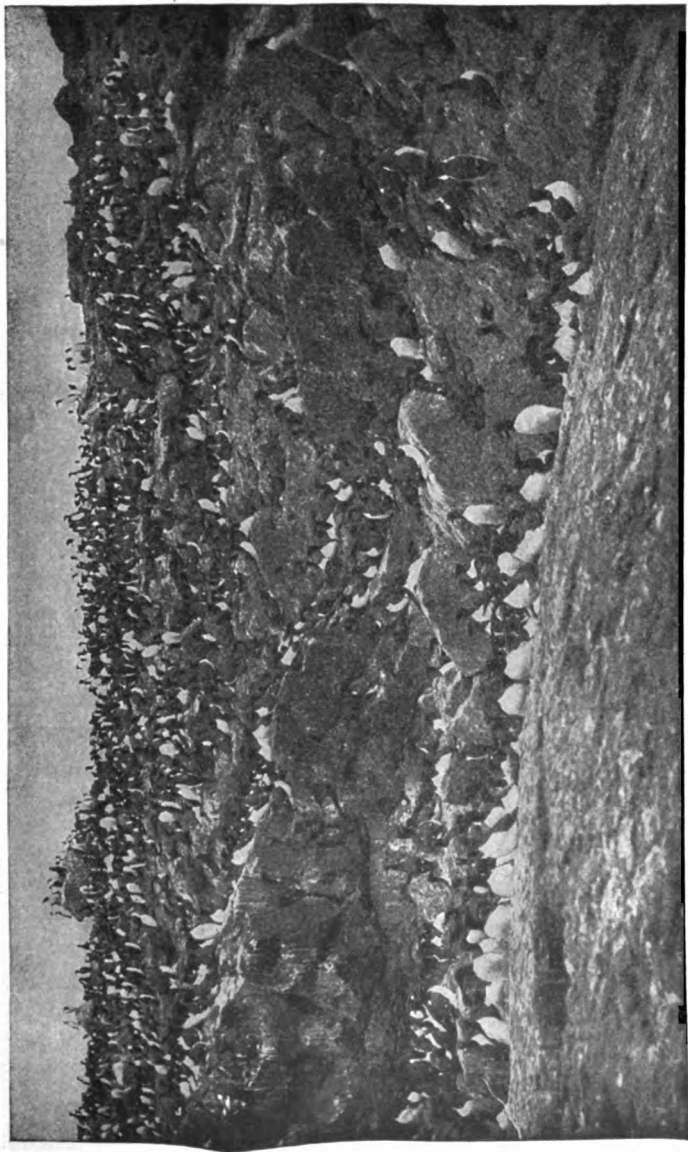


FIG. 100.—Pallas's murres (*Uria lomvia arra*) assembled on Walrus Island, one of the Pribilof group in Bering Sea. Photograph by HARRY CHICHESTER, photographer for the Fur Seal Commission.

about the dead body of a horse. The food found by the first was being shared by all. The association of pelicans in fishing is a good example of the advantage of a gregarious and mutually helpful habit. The pelicans sometimes go fishing in great bands, and, after having chosen an appropriate place near the shore, they form a wide half-circle facing the shore, and narrow it by paddling toward the land, catching the fish which they inclose in the ever-narrowing circle.

The wary Rocky Mountain sheep (Fig. 101) live together in small bands, posting sentinels whenever they are feeding or resting, who watch for and give warning of the approach of enemies. The beavers furnish a well-known and very interesting example of mutual help, and they exhibit a truly communal life, although a simple one. They live in "villages" or communities, all helping to build the dam across the stream, which is necessary to form the broad marsh or pool in which the nests or houses are built. Prairie-dogs live in great villages or communities which spread over many acres. They tell each other by shrill cries of the approach of enemies, and they seem to visit each other and to enjoy each other's society a great deal, although that they afford each other much actual active help is not apparent. Birds in migration are gregarious, although at other times they may live comparatively alone. In their long flights they keep together, often with definite leaders who seem to discover and decide on the course of flight for the whole great flock. The wedge-shaped flocks of wild geese flying high and uttering their sharp, metallic call in their southward migrations are well known in many parts of the United States. Indeed, the more one studies the habits of animals the more examples of social life and mutual help will be found. Probably most animals are in some degree gregarious in habit, and in all cases of gregariousness there is probably some degree of mutual aid.

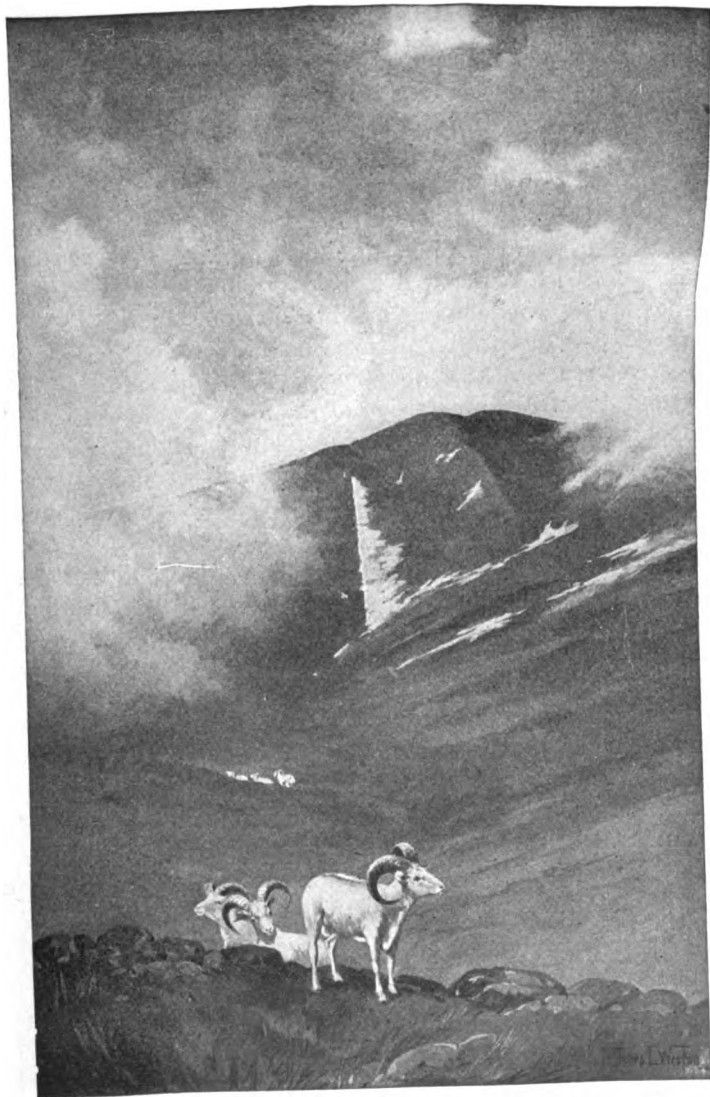


FIG. 101.—Rocky Mountain or bighorn sheep. By permission of the publishers of Outing.

88. Division of labor and basis of communal life.—We have learned in Chapters II and IV that the complexity of the bodies of the higher animals depends on a specialization or differentiation of parts, due to the assumption of different functions or duties by different parts of the body; that the degree of structural differentiation depends on the degree or extent of division of labor shown in the economy of the animal. It is obvious that the same principle of division of labor with accompanying modification of structure is the basis of colonial and communal life. It is simply a manifestation of the principle among individuals instead of among organs. The division of the necessary labors of life among the different zooids of the colonial jelly-fish is plainly the reason for the profound and striking, but always reasonable and explicable modifications of the typical polyp or medusa body, which is shown by the swimming zooids, the feeding zooids, the sense zooids, and the others of the colony. And similarly in the case of the termite community, the soldier individuals are different structurally from the worker individuals because of the different work they have to do. And the queen differs from all the others, because of the extraordinary prolificacy demanded of her to maintain the great community.

It is important to note, however, that among those animals that show the most highly organized or specialized communal or social life, the structural differences among the individuals are the least marked, or at least are not the most profound. The three kinds of honey-bee individuals differ but little; indeed, as two of the kinds, male and female, are to be found in the case of almost all kinds of animals, whether communal in habit or not, the only unusual structural specialization in the case of the honey-bee, is the presence of the worker individual, which differs from the usual individuals in but little more than the rudimentary condition of the reproductive glands. Finally, in the case of man, with whom the communal or social habit is so

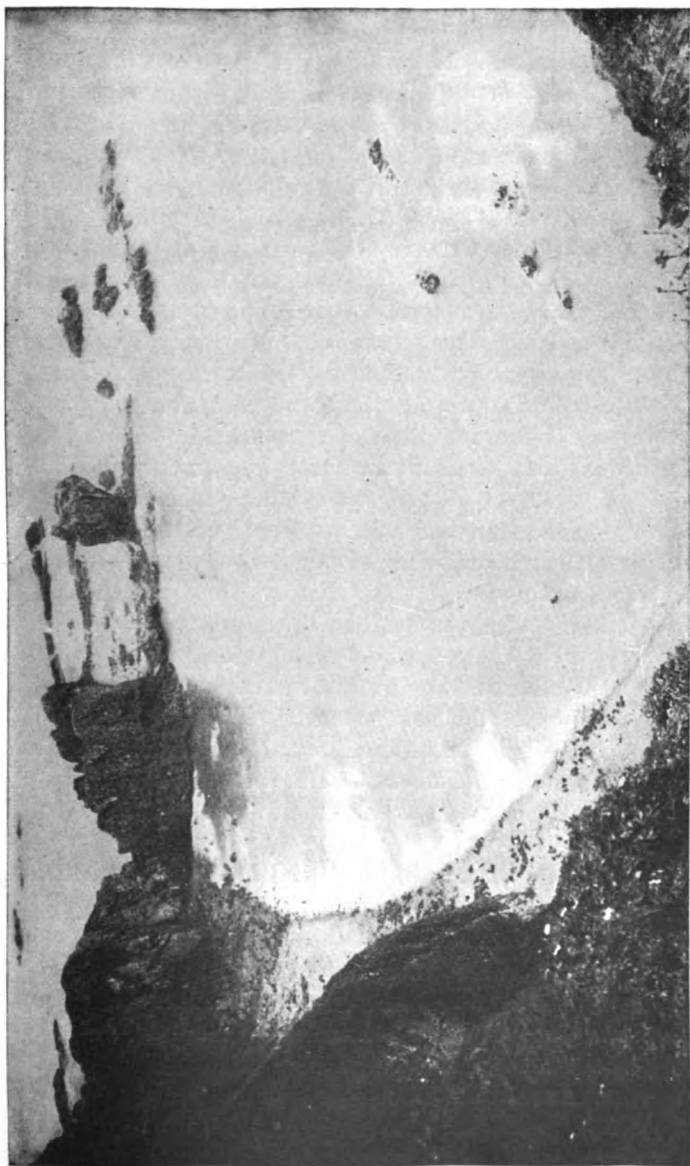


FIG. 102.—Fur-seal rookeries or groups of homes at Zapalata on Medni, one of the Commander Islands, off Kamchatka. The seals are the small spots gathered in groups on the white beach at the foot of the cliffs. The fur seals live gregariously. Photograph by D. W. THOMPSON and A. MARRETT.

all-important as to gain for him the name of "the social animal," there is no differentiation of individuals adapted only for certain kinds of work. Among these highest examples of social animals, the presence of an advanced mental endowment, the specialization of the mental power, the power of reason, have taken the place of and made unnecessary the structural differentiation of individuals. The honey-bee workers do different kinds of work: some gather food, some care for the young, and some make wax and build cells, but the individuals are interchangeable; each one knows enough to do these various things. There is a structural differentiation in the matter of only one special work or function, that of reproduction.

With the ants there is, in some cases, a considerable structural divergence among individuals, as in the genus *Atta* of South America with six kinds of individuals—namely, winged males, winged females, wingless soldiers, and wingless workers of three distinct sizes. In the case of other kinds with quite as highly organized a communal life there are but three kinds of individuals, the winged males and females and the wingless workers. The workers gather food, build the nest, guard the "cattle" (aphids), make war, and care for the young. Each one knows enough to do all these various distinct things. Its body is not so modified that it can do but one kind of thing, which thing it must always do.

The increase of intelligence, the development of the power of reasoning, is the most potent factor in the development of a highly specialized social life. Man is the example of the highest development of this sort in the animal kingdom, but the highest form of social development is not by any means the most perfectly communal.

89. Advantages of communal life.—The advantages of communal or social life, of co-operation and mutual aid, are real. The animals that have adopted such a life are among the most successful of all animals in the struggle for exist-

ence. The termite individual is one of the most defenseless, and, for those animals that prey on insects, one of the most toothsome luxuries to be found in the insect world. But the termite is one of the most abundant and widespread and successfully living insect kinds in all the tropics. Where ants are not, few insects are. The honey-bee is a popular type of a successful life. The artificial protection afforded the honey-bee by man may aid in its struggle for existence, but it gains this protection because of certain features of its communal life, and in Nature the honey-bee takes care of itself well. The Little Bee People of Kipling's *Jungle Book*, who live in great communities in the rocks of Indian hills, can put to rout the largest and fiercest of the jungle animals. Co-operation and mutual aid are among the most important factors which help in the struggle for existence. Its great advantages are, however, in some degree balanced by the fact that mutual help brings mutual dependence. The community or society can accomplish greater things than the solitary individuals, but co-operation limits freedom, and often sacrifices the individual to the whole.

CHAPTER X

COMMENSALISM AND SYMBIOSIS

90. **Association between animals of different species.**—The living together and mutual help discussed in the last chapter concerned in each instance a single species of animal. All the various members of a pack of wolves or of a community of ants are individuals of the same species. But there are many instances of an association of individuals of different kinds of animals. The number of individuals concerned, however, is usually but two—that is, one of each of the two kinds of animals. In many cases of an association of individuals of different species one kind derives great benefit and the other suffers more or less injury from the association. One kind lives at the expense of the other. This association is called parasitism, and is discussed in the next chapter. In some cases, however, neither kind of animal suffers from the presence of the other. The two live together in harmony and presumably to their mutual advantage. In some cases this mutual advantage is obvious. This kind of association is called *commensalism* or *symbiosis*. The term commensalism may be used to denote a condition where the two animals are not so intimately associated nor derive such obvious mutual advantage from the association, as in that condition of very intimate and permanent association with obvious co-operative and marked advantage that may be called symbiosis. A few examples of each of these interesting conditions of association between which it is impossible to make any sharp distinction, will be given.

91. **Commensalism.**—A curious example of commensalism is afforded by the different species of Remoras (*Echeneididae*) which attach themselves to sharks, barracudas, and other large fishes by means of a sucking disk on the top of the head (Fig. 103). This disk is made by a modification of



FIG. 103.—Remora, with dorsal fin modified to be a sucking plate by which the fish attaches itself to a shark.

the dorsal fin. The Remora thus attached to a shark may be carried about for weeks, leaving its host only to secure food. This is done by a sudden dash through the water. The Remora injures the shark in no way save, perhaps, by the slight check its presence gives to the shark's speed in swimming.

Whales, similarly, often carry barnacles about with them. These barnacles are permanently attached to the skin of the whale just as they would be to a stone or wooden pile. Many small crustaceans, annelids, mollusks, and other invertebrates burrow into the substance of living sponges, not for the purpose of feeding on them, but for shelter. On the other hand, the little boring sponge (*Cliona*) burrows in the shells of oysters and other bivalves for protection. These are hardly true cases of even that lesser degree of mutually advantageous association which we are calling commensalism. But some species of sponge "are never found growing except on the backs or legs of certain crabs." In these cases the sponge, with its many plant-like branches, protects the crab by concealing it from its enemies, while the sponge is benefited by being carried about by the crab to new food supplies. Certain sponges

and polyps are always found growing in close association, though what the mutual advantage of this association is has not yet been found out.

Among the coral reefs near Thursday Island (between New Guinea and Australia) there lives an enormous kind of sea-anemone or polyp. Individuals of this great polyp measure two feet across the disk when fully expanded. In the interior, the stomach cavity, which communicates freely with the outside by means of the large mouth opening at the free end of the polyp, there may often be found a small fish (*Amphiprion percula*). That this fish is purposely in the gastral cavity of the polyp is proved by the fact that when it is dislodged it invariably returns to its singular lodging-place. The fish is brightly colored, being of a brilliant vermilion hue with three broad white cross bands. The discoverer of this peculiar habit suggests that there are mutual benefits to fish and polyp from this habit. "The fish being conspicuous, is liable to attacks, which it escapes by a rapid retreat into the sea-anemone; its enemies in hot pursuit blunder against the outspread tentacles of the anemone and are at once narcotized by the 'thread cells' shot out in innumerable showers from the tentacles, and afterward drawn into the stomach of the anemone and digested."

Small fish of the genus *Nomeus* may often be found accompanying the beautiful Portuguese man-of-war (*Physalia*) as it sails slowly about on the ocean's surface (Fig. 104). These little fish lurk underneath the float and among the various hanging thread-like parts of the *Physalia*, which are provided with stinging cells. The fish are protected from their enemies by their proximity to these stinging threads, but of what advantage to the man-of-war their presence is is not understood. Similarly, several kinds of medusæ are known to harbor or to be accompanied by young or small adult fishes.

In the nests of the various species of ants and termites

many different kinds of other insects have been found. Some of these are harmful to their hosts, in that they feed on the food stores gathered by the industrious and provident ant, but others appear to feed only on refuse or useless substances in the nest. Some may even be of help to their hosts. Over one thousand species of these myrmecophilous (ant-loving) and termitophilous (termite-loving) insects have been recorded by collectors as living habitually in the nests of ants and termites. The owls and rattlesnakes which live with the prairie-dogs in their villages afford a familiar example of commensalism.

92. **Symbiosis.**—Of a more intimate character, and of more obvious and certain mutual advantage, is the well-known case of the symbiotic association of some of the numerous species of hermit-crabs and certain species of sea-anemones. The hermit-crab always takes for his habitation the shell of another animal, often that of the common whelk. All of the hind part of the crab lies inside the shell, while its head with its great claws project from the opening of the shell. On the surface of the shell near the opening there is often to be found a sea-anemone, or sea-rose (Fig. 105).



FIG 104.—A Portuguese man-of-war (*Physalia*), with man-of-war fishes (*Nemus gronovii*) living in the shelter of the stinging feelers. Specimens from off Tampa, Fla.

This sea-anemone is fastened securely to the shell, and has its mouth opening and tentacles near the head of the crab. The sea-anemone is carried from place to place by the hermit-crab, and in this way is much aided in obtaining food. On the other hand, the crab is protected from its enemies by the well-armed and dangerous tentacles of the sea-anem-

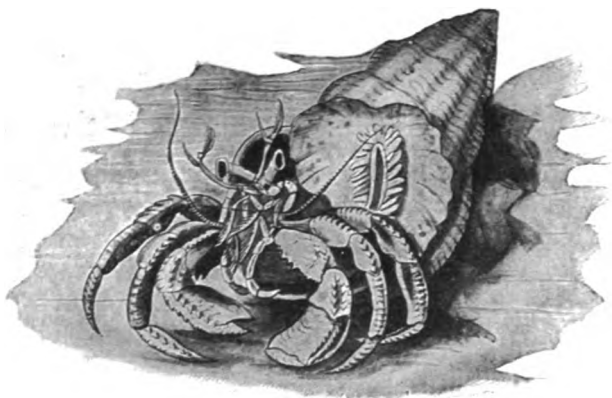


FIG. 105.—Hermit-crab (*Pagurus*) in shell, with a sea-anemone (*Adamsia palliata*) attached to the shell.—After HERTWIG.

one. In the tentacles there are many thousand long, slender stinging threads, and the fish that would obtain the hermit-crab for food must first deal with the stinging anemone. There is no doubt here of the mutual advantage gained by these two widely different but intimately associated companions. If the sea-anemone be torn away from the shell inhabited by one of these crabs, the crab will wander about, carefully seeking for another anemone. When he finds it he struggles to loosen it from its rock or from whatever it may be growing on, and does not rest until he has torn it loose and placed it on his shell.

There are numerous small crabs called pea-crabs (*Pinnotheres*) which live habitually inside the shells of living

mussels. The mussels and the crabs live together in perfect harmony and to their mutual benefit.

There are a few extremely interesting cases of symbiosis in which not different kinds of animals are concerned, but animals and plants. It has long been known that some sea-anemones possess certain body cells which contain chlorophyll, that green substance characteristic of the green plants, and only in few cases possessed by animals. When these chlorophyll-bearing sea-anemones were first found, it was believed that the chlorophyll cells really belonged to the animal's body, and that this condition



FIG. 106.—The crab *Epizoanthus paguriphilus*, with the sea-anemone *Parapagurus pilosistranus* on its shell.

broke down one of the chiefest and most readily apparent distinctions between animals and plants. But it is now known that these chlorophyll-bearing cells are microscopic, one-celled plants, green algæ, which live habitually in the bodies of the sea-anemone. It is a case of true symbiosis. The algæ, or plants, use as food the carbonic-acid gas which is given off in the respiratory processes of the sea-anemone, and the sea-anemone breathes in the oxygen given off by the algæ in the process of extracting the carbon for food from the carbonic-acid gas. These algæ, or one-celled plants, lie regularly only in the innermost of the three cell layers which compose the wall

or body of the sea-anemone (Fig. 107). They penetrate into and lie in the interior of the cells of this layer whose special function is that of digestion. They give this innermost layer of cells a distinct green color.

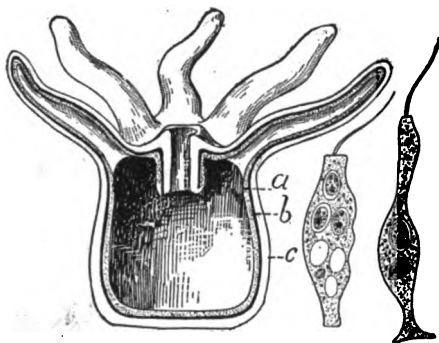


FIG. 107.—Diagrammatic section of sea-anemone. *a*, the inner cell layer containing alga cells, the two isolated cells at right being cells of this layer with contained algæ; *b*, middle body wall layer; *c*, outer body wall layer.—After HERTWIG.

There are other examples known of the symbiotic association of plants and animals; and if we were to follow the study of symbiosis into the plant kingdom we should find that in one of the large groups of plants, the familiar lichens which grow on

rocks and tree trunks and old fences, every member lives symbiotically. A lichen is not a single plant, but is always composed of two plants, an alga (chlorophyll-bearing) and a fungus (without chlorophyll) living together in a most intimate, mutually advantageous association.

CHAPTER XI

PARASITISM AND DEGENERATION

93. **Relation of parasite and host.**—In addition to the various ways of living together of animals already described, namely, the social life of individuals of a single species and the commensal and symbiotic life of individuals of different species, there is another kind of association among animals that is very common. In cases of symbiosis the two animals living together are of mutual advantage to each other; both profit by the association. But there are many instances in the animal kingdom of an association between two animals by which one gains advantages great or small, sometimes even obtaining all the necessities of life, while the other gains nothing, but suffers corresponding disadvantage, often even the loss of life itself. This is the association of parasite and host; the relation between two animals whereby one, the parasite, lives on or in the other, the host, and at the expense of the host. Parasitism is a common phenomenon in all groups of animals, although the parasites themselves are for the most part confined to the classes of invertebrates. Among the simplest animals or Protozoa there are parasites, as *Gregarina*, which lives in the bodies of insects and crustaceans; there are parasitic worms, and parasitic crustaceans and mollusks and insects, and a few vertebrates. When an animal can get along more safely or more easily by living at the expense of some other animal and takes up such a life, it becomes a parasite. Parasitism is naturally, therefore, not confined to any one group or class of animals.

94. **Kinds of parasitism.**—The bird-lice (Mallophaga), which infest the bodies of all kinds of birds and are found especially abundant on domestic fowls, live upon the outside of the bodies of their hosts, feeding upon the feathers and dermal scales. They are examples of *external parasites*. Other examples are fleas and ticks, and the crustaceans called fish-lice and whale-lice, which are attached to marine animals. On the other hand, almost all animals are infested by certain parasitic worms which live in the alimentary canal, like the tape-worm, or imbedded in the muscles, like the trichina. These are examples of *internal parasites*. Such parasites belong mostly to the class of worms, and some of them are very injurious, sucking the blood from the tissues of the host, while others feed solely on the partly digested food. There are also parasites that live partly within and partly on the outside of the body, like the *Sacculina*, which lives on various kinds of crabs. The body of the *Sacculina* consists of a soft sac which lies on the outside of the crab's body, and of a number of long, slender root-like processes which penetrate deeply into the crab's body, and take up nourishment from within. The *Sacculina* is itself a crustacean or crab-like creature. The classification of parasites as external and internal is purely arbitrary, but it is often a matter of convenience.

Some parasites live for their whole lifetime on or in the body of the host, as is the case with the bird-lice. Their eggs are laid on the feathers of the bird host; the young when hatched remain on the bird during growth and development, and the adults only rarely leave the body, usually never. These may be called *permanent parasites*. On the other hand, fleas leap off or on a dog as caprice dictates; or, as in other cases, the parasite may pass some definite part of its life as a free, non-parasitic organism, attaching itself, after development, to some animal, and remaining there for the rest of its life. These parasites may be called *temporary parasites*. But this grouping or classification,

like that of the external and internal parasites, is simply a matter of convenience, and does not indicate at all any blood relationship among the members of any one group.

95. **The simple structure of parasites.**—In all cases the body of a parasite is simpler in structure than the body of other animals which are closely related to the parasite—that is, animals that live parasitically have simpler bodies than animals that live free active lives, competing for food with the other animals about them. This simplicity is not primitive, but results from the loss or atrophy of the structures which the mode of life renders useless. Many parasites are attached firmly to their host, and do not move about. They have no need of the power of locomotion. They are carried by their host. Such parasites are usually without wings, legs, or other locomotory organs. Because they have given up locomotion they have no need of organs of orientation, those special sense organs like eyes and ears and feelers which serve to guide and direct the moving animal; and most non-locomotory parasites will be found to have no eyes, nor any of the organs of special sense which are accessory to locomotion and which serve for the detection of food or of enemies. Because these important organs, which depend for their successful activity on a highly organized nervous system, are lacking, the nervous system of parasites is usually very simple and undeveloped. Again, because the parasite usually has for its sustenance the already digested highly nutritious food elaborated by its host, most parasites have a very simple alimentary canal, or even no alimentary canal at all. Finally, as the fixed parasite leads a wholly sedentary and inactive life, the breaking down and rebuilding of tissue in its body go on very slowly and in minimum degree, and there is no need of highly developed respiratory and circulatory organs; so that most fixed parasites have these systems of organs in simple condition. Altogether the body of a fixed, permanent parasite is so simplified and so want-

ing in all those special structures which characterize the higher, active, complex animals, that it often presents a very different appearance from those animals with which we know it to be nearly related.

The simplicity of parasites does not indicate that they all belong to the groups of primitive simple animals. Parasitism is found in the whole range of animal life, from primitive to highest. Their simplicity is something that has resulted from their mode of life. It is the result of a change in the body-structure which we can often trace in the development of the individual parasite. Many parasites in their young stages are free, active animals with a better or more complex body than they possess in their fully developed or adult stage. The simplicity of parasites is the result of degeneration—a degeneration that has been brought about by their adoption of a sedentary, non-competitive parasitic life. And this simplicity of degeneration, and the simplicity of primitiveness should be sharply distinguished. Animals that are primitively simple have had only simple ancestors; animals that are simple by degeneration often have had highly organized, complex ancestors. And while in the life history or development of a primitively simple animal all the young stages are simpler than the adult, in a degenerate animal the young stages may be, and usually are, more complex and more highly organized than the adult stage.

In the examples of parasitism that are described in the following pages all these general statements are illustrated.

96. *Gregarina*.—In the intestines of cray-fishes, centipeds, and several kinds of insects may often be found certain one-celled animals (Protozoa) which are living as parasites. Their food, which they take into their minute body by absorption, is the intestinal fluids in which they lie. These parasitic Protozoa belong to the genus *Gregarina* (Fig. 9) (see Chapter I). Because the body of any

protozoan is as simple as an animal's body can be, being composed of but a single cell, degeneration can not occur in the cases of these parasites. There are, besides *Gregarina*, numerous other parasitic one-celled animals, several kinds living inside the cells of their host's body. One kind lives in the blood-corpuscles of the frog, and another in the cells of the liver of the rabbit.

97. **The tape-worm and other flat-worms.**—In the great group of flat-worms (Platyhelminthes), that group of animals which of all the principal animal groups is widest in its distribution, perhaps a majority of the species are parasites. Instead of being the exception, the parasitic life is the rule among these worms. Of the three classes into which the flat-worms are divided almost all of the members of two of the classes are parasites. The common tape-worm (*Tænia*) (Fig. 108), which lives parasitically in the intestine of man, is a good example of one of these classes. "It has the form of a narrow ribbon, which may attain the length of several yards, attached at one end to the wall of the intestine, the remainder hanging freely in the interior." Its body is composed of segments or serially arranged parts, of which there are about eight hundred and fifty altogether. It has no mouth nor alimentary canal. It feeds simply by absorbing into its body, through the surface, the nutritious, already digested liquid food in the intestine. There are no eyes nor other special sense organs, nor any organs of locomotion. The body is very degenerate. The life history of the tape-worm is interesting, because of the necessity of

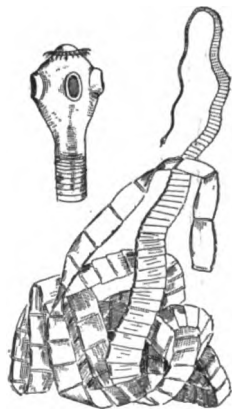


FIG. 108.—Tape-worm (*Tænia solium*). In upper left-hand corner of figure the head much magnified. — After LEUCKART.

two hosts for its completion. The eggs of the tape-worm pass from the intestine with the excreta, and must be taken into the body of some other animal in order to develop. In the case of one of the several species of tape-worms that infest man this other host must be the pig. In the alimentary canal of the pig the young tape-worm develops, and later bores its way through the walls of the canal and becomes imbedded in the muscles. There it lies, until it finds its way into the alimentary canal of man by his eating the flesh of the pig. In the intestine of man the tape-worm continues to develop until it becomes full grown.

In a lake in Yellowstone Park the suckers are infested by one of the flat-worms (*Ligula*) that attains a size of nearly one fourth the size of the fish in whose intestines it lives. If the tape-worm of man attained such a comparative size, a man of two hundred pounds' weight would be infested by a parasite of fifty pounds' weight.

98. *Trichina* and other round-worms.—Another group of animals, many of whose numbers are parasites, are the round-worms or thread-worms (*Nemathelminthes*). The free-living round-worms are active, well-organized animals, but the parasitic kinds all show a greater or less degree of degeneration. One

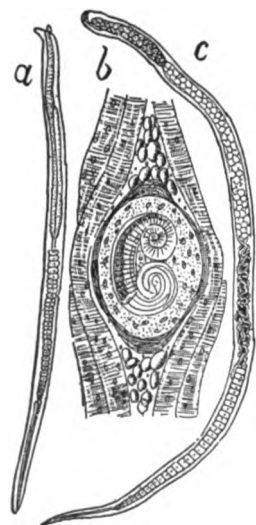


FIG. 109. — *Trichina spiralis* (after CLAUS). a, male; b, encysted form in muscle; c, female.

of the most terrible parasites of man is a round-worm called *Trichina spiralis* (Fig. 109). It is a minute worm, from one to three millimetres long, which in its adult condition lives in the intestine of man or of the pig or other mammals. The young are born alive and bore through the walls

of the intestine. They migrate to the voluntary muscles of the hosts, especially those of the limbs and back, and here each worm coils itself up in a muscle fiber and becomes inclosed in a spindle-shaped cyst or cell (Fig. 109, b). A single muscle may be infested by hundreds of thousands of these minute worms. It has been estimated that fully one hundred million encysted worms have existed in the muscles of a "trichinized" human body. The muscles undergo more or less degeneration, and the death of the host may occur. It is necessary, for the further development of the worms, that the flesh of the host be eaten by another mammal, as the flesh of the pig by man, or the flesh of man by a pig or rat. The *Trichinæ* in the alimentary canal of the new host develop into active adult worms and produce new young.

In the Yellowstone Lake the trout are infested by the larvæ or young of a round-worm (*Bothriocephalus cordiceps*) which reaches a length of twenty inches, and which is often found stitched, as it were, through the viscera and the muscles of the fish. The infested trout become feeble and die, or are eaten by the pelicans which fish in this lake. In the alimentary canal of the pelican the worms become adult, and parts of the worms containing eggs escape from the alimentary canal with the excreta. These portions of worms are eaten by the trout, and the eggs give birth to new worms which develop in the bodies of the fish with disastrous effects. It is estimated that for each pelican in Yellowstone Lake over five million eggs of the parasitic worms are discharged into the lake.

The young of various carnivorous animals are often infested by one of the species of round-worms called "pup-worms" (*Uncinaria*). Recent investigations show that thousands of the young or pup fur-seals are destroyed each year by these parasites. The eggs of the worm lie through the winter in the sands of the breeding grounds of the fur-seal. The young receive them from the fur of the mother

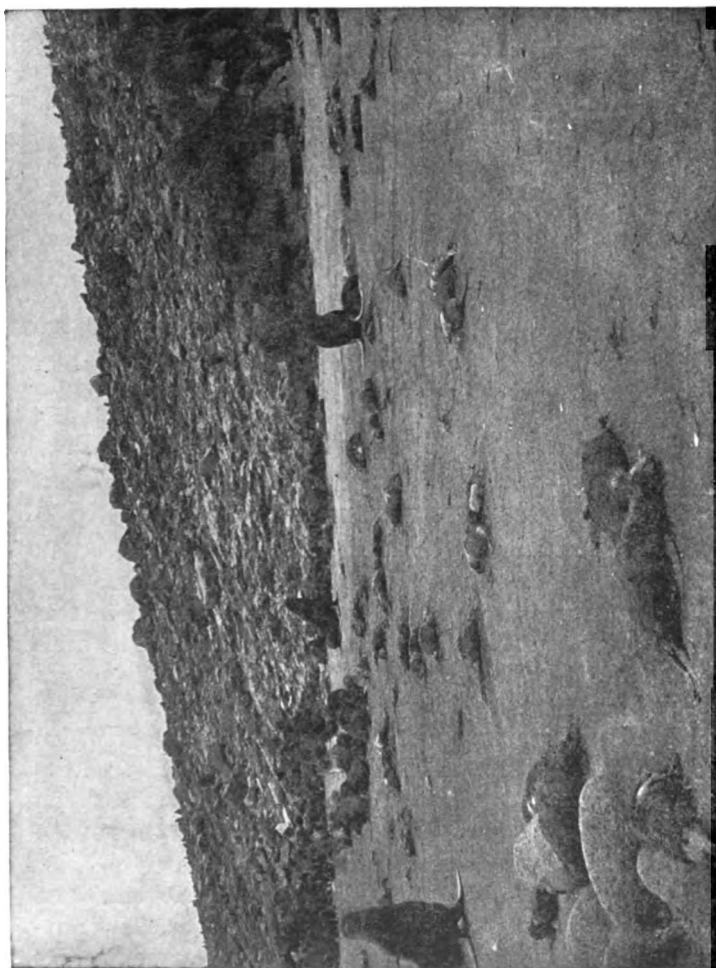


FIG. 110.—Fur-seal pups, killed by a parasitic worm (*Unchinaria*), on the sands of Tolstol rookery, St. Paul Island, Friblof group. Photograph by C. H. Townsend.

and the worm develops in the upper intestine. It feeds on the blood of the young seal, which finally dies from anæmia. On the beaches of the seal islands in Bering Sea there are sometimes hundreds of dead seal pups which have been killed by this parasite (Fig. 110).

99. *Sacculina*.—Among the more highly organized animals the results of a parasitic life, in degree of structural degeneration, can be more readily seen. A well-known parasite, belonging to the crustacea—the class of shrimps, crabs, lobsters, and cray-fishes—is *Sacculina*. The young *Sacculina* is an active, free-swimming larva much like a young prawn or young crab. But the adult bears absolutely no resemblance to such a typical crustacean as a cray-fish or crab. The *Sacculina* after a short period of independent existence at-

taches itself to the abdomen of a crab, and there completes its development while living as a parasite. In its adult condition (Fig. 111) it is simply a great tumor-like sac, bearing many delicate root-

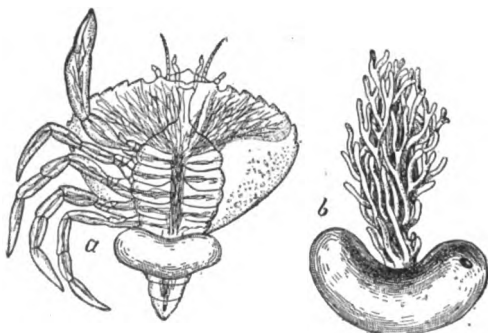


FIG. 111.—*Sacculina*, a crustacean parasite of crabs. *a*, attached to a crab, with root-like processes penetrating the crab's body; *b*, removed from the crab.

like suckers which penetrate the body of the crab host and absorb nutriment. The *Sacculina* has no eyes, no mouth parts, no legs, or other appendages, and hardly any of the usual organs except reproductive organs. Degeneration here is carried very far.

Other parasitic crustacea, as the numerous kinds of fish-lice (Fig. 112) which live attached to the gills or to

other parts of fish, and derive all their nutriment from the body of the fish, show various degrees of degeneration. With

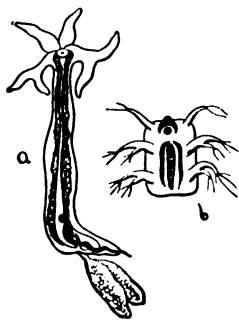


FIG. 112. — Fish-lice (*Lernæocera*). *a*, adult; *b*, larva.

some of these fish-lice the female, which looks like a puffed-out worm, is attached to the fish or other aquatic animal, while the male, which is perhaps only a tenth of the size of the female, is permanently attached to the female, living parasitically on her.

100. **Parasitic insects.** — Among the insects there are many kinds that live parasitically for part of their life, and not a few that live as parasites for their whole life. The true sucking lice (Fig. 113) and the bird-lice (Fig. 114) live for their whole lives as external parasites on the bodies of their host, but they are not fixed — that is, they retain their legs and power of locomotion, although they have lost their wings through degeneration. The eggs of the lice are deposited on the hair of the mammal or bird that

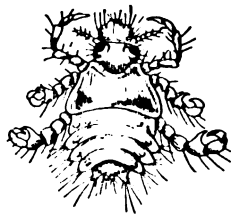


FIG. 113. — Sucking louse (*Pediculus*) of human body.



FIG. 114. — Bird louse (*Lipeurus densus*).

serves as host; the young hatch and immediately begin to live as parasites, either sucking the blood or feeding on the

hair or feathers of the host. In the order Hymenoptera there are several families, all of whose members live during their larval stage as parasites. We may call all these hymenopterous parasites ichneumon flies. The ichneumon flies are parasites of other insects, especially of the larvæ of beetles and moths and butterflies. In fact, the ichneumon flies do more to keep in check the increase of injurious and destructive caterpillars than do all our artificial remedies for these insect pests. The adult ichneumon fly is four-winged and lives an active, independent life. It lays its eggs either in or on or near some caterpillar or beetle grub, and the young ichneumon, when hatched, burrows about in the body of its host, feeding on its tissues, but not attacking such organs as the heart or nervous ganglia, whose injury would mean immediate death to the host. The caterpillar lives with the ichneumon grub within it, usually until nearly



FIG. 115.—Parasitized caterpillar from which the ichneumon fly parasites have issued, showing the circular holes of exit in the skin.

time for its pupation. In many instances, indeed, it pupates, with the parasite still feeding within its body, but it never comes to maturity. The larval ichneumon fly pupates either within the body of its host (Fig. 115) or in a tiny silken cocoon outside of its body (Fig. 116). From the cocoons the adult winged ichneumon flies emerge, and after mating find another host on whose body to lay their eggs.

One of the most interesting ichneumon flies is *Thalessa* (Fig. 119), which has a remarkably long, slender, flexible ovipositor, or egg-laying organ. An insect known as the

pigeon horn-tail (*Tremex columba*) (Fig. 117) deposits its eggs, by means of a strong, piercing ovipositor, half an inch deep in the trunk wood of growing trees. The young or

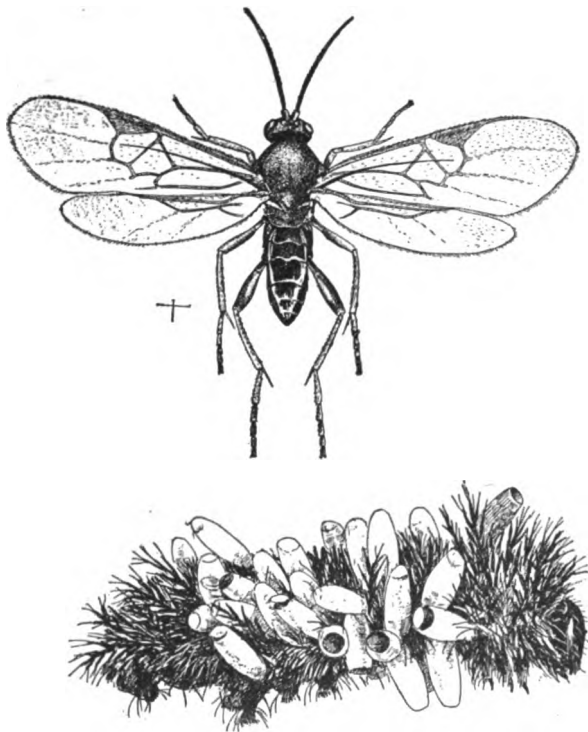


FIG. 116.—Caterpillar with cocoons of the pupae of ichneumon fly parasites, and (above) one of the adult ichneumon flies. The lines indicate natural dimensions.

larval *Tremex* is a soft-bodied white grub, which bores deeply into the trunk of the tree, filling up the burrow behind it with small chips. The *Thalessa* is a parasite of the *Tremex*, and "when a female *Thalessa* finds a tree infested by *Tremex*, she selects a place which she judges is opposite

a *Tremex* burrow, and, elevating her long ovipositor in a loop over her back, with its tip on the bark of the tree (Fig.



FIG. 117.—The pigeon horn-tail (*Tremex columba*), with strong boring ovipositor.

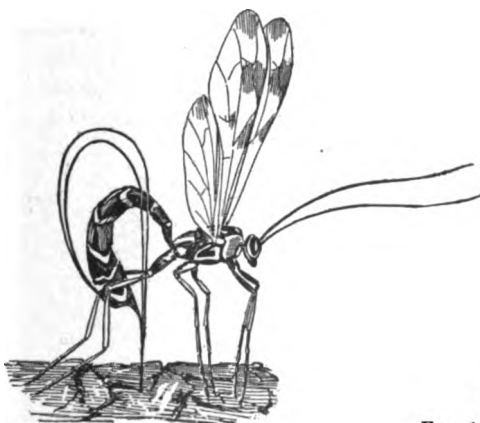


FIG. 118.—*Thalesa lunator* boring.—After COMSTOCK.

118), she makes a derrick out of her body and proceeds with great skill and precision to drill a hole into the tree. When the *Tremex* burrow is reached she deposits an egg in it.

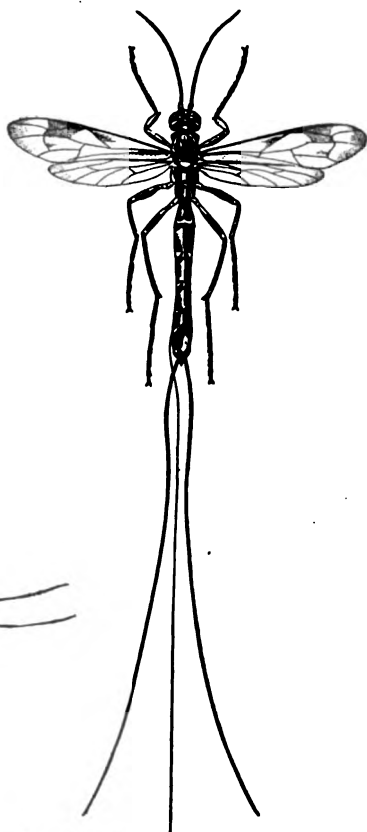


FIG. 119.—The large ichneumon fly *Thalesa*, with long flexible ovipositor. The various parts of this ovipositor are spread apart in the figure; naturally they lie together to form a single piercing organ.

The larva that hatches from this egg creeps along this burrow until it reaches its victim, and then fastens itself to the horn-tail larva, which it destroys by sucking its blood.

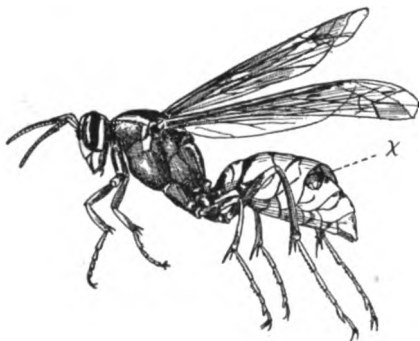


FIG. 120.—Wasp (*Polistes*), with female *Stylops* parasite (x) in body.

The larva of *Thalesa*, when full grown, changes to a pupa within the burrow of its host, and the adult gnaws a hole out through the bark if it does not find the hole already made by the *Tremex*."

The beetles of the family Stylopidae present an interesting case of parasitism. The adult males are winged, but the adult females are wingless and grub-like. The larval stylopid attaches itself to a wasp or bee, and bores into its abdomen. It pupates within the abdomen of the wasp or bee, and lies there with its head projecting slightly from a suture between two of the body rings of its host (Fig. 120). The adult finally issues and leaves the host's body.

Almost all of the mites and ticks, which are more nearly allied to the spiders than to the true insects, live parasitically. Most of them live as external parasites, sucking the blood of their host, but some live underneath the skin like the itch-mites (Fig. 121), which cause, in man, the disease known as the itch.

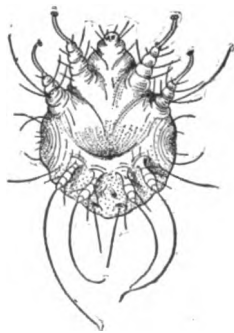


FIG. 121.—The itch-mite (*Sarcoptes scabiei*).

101. **Parasitic vertebrates.**—Among the vertebrate animals there are not many examples of true parasitism. The hag-fishes or borers (*Myxine*, *Heptatrema*, *Polistotrema*) are long and cylindrical, eel-like creatures, very slimy and very low in structure. The mouth is without jaws, but forms a sucking disk, by which the hag-fish attaches itself to the body of some other fish. By means of the rasping teeth on its tongue, it makes a round hole through the skin, usually at the throat. It then devours all the muscular substance of the fish, leaving the viscera untouched. When the fish finally dies it is a mere hulk of skin, scales, bones, and viscera, nearly all the muscle being gone. Then the hag-fish slips out and attacks another individual.

The lamprey, another low fish, in similar fashion feeds leech-like on the blood of other fishes, which it obtains by lacerating the flesh with its rasp-like teeth, remaining attached by the round sucking disk of its mouth.

Certain birds, as the cow-bird and the European cuckoo, have a parasitic habit, laying their eggs in the nests of other birds, leaving their young to be hatched and reared by their unwilling hosts. This is, however, not bodily parasitism, such as is seen among lower forms.

102. **Degeneration through quiescence.**—While parasitism is the principal cause of degeneration among animals, yet it is not the sole cause. It is evident that if for any other reason animals should become fixed, and live inactive or sedentary lives, they would degenerate. And there are not a few instances of degeneration due simply to a quiescent life, unaccompanied by parasitism. The Tunicata, or sea-squirts (Fig. 122), are animals which have become simple through degeneration, due to the adoption of a sedentary life, the withdrawal from the crowd of animals and from the struggle which it necessitates. The young tunicate is a free-swimming, active, tadpole-like or fish-like creature, which possesses organs very like those of the adult of the simplest fishes or fish-like forms. That is, the sea-squirt

begins life as a primitively simple vertebrate. It possesses in its larval stage a notochord, the delicate structure which precedes the formation of a backbone, extending along the

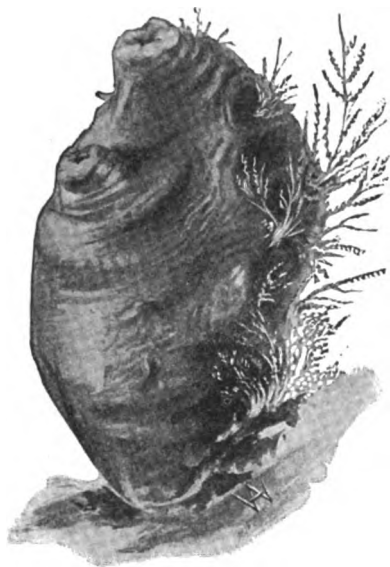


FIG. 122.—A sea-squirt, or tunicate.

upper part of the body, below the spinal cord. It is found in all young vertebrates, and is characteristic of the class. The other organs of the young tunicate are all of vertebral type. But the young sea-squirt passes a period of active and free life as a little fish, after which it settles down and attaches itself to a stone or shell or wooden pier by means of suckers, and remains for the rest of its life fixed. Instead of going on and developing into a fish-like creature, it loses its notochord, its special sense organs, and

other organs; it loses its complexity and high organization, and becomes a "mere rooted bag with a double neck," a thoroughly degenerate animal.

A barnacle is another example of degeneration through quiescence. The barnacles are crustaceans related most nearly to the crabs and shrimps. The young barnacle just from the egg (Fig. 123, *f*) is a six-legged, free-swimming nauplius, very like a young prawn or crab, with single eye. In its next larval stage it has six pairs of swimming feet, two compound eyes, and two large antennæ or feelers, and still lives an independent, free-swimming life. When it makes its final change to the adult condition, it attaches

itself to some stone or shell, or pile or ship's bottom, loses its compound eyes and feelers, develops a protecting shell, and gives up all power of locomotion. Its swimming feet become changed into grasping organs, and it loses most of its outward resemblances to the other members of its class (Fig. 123, *e*).

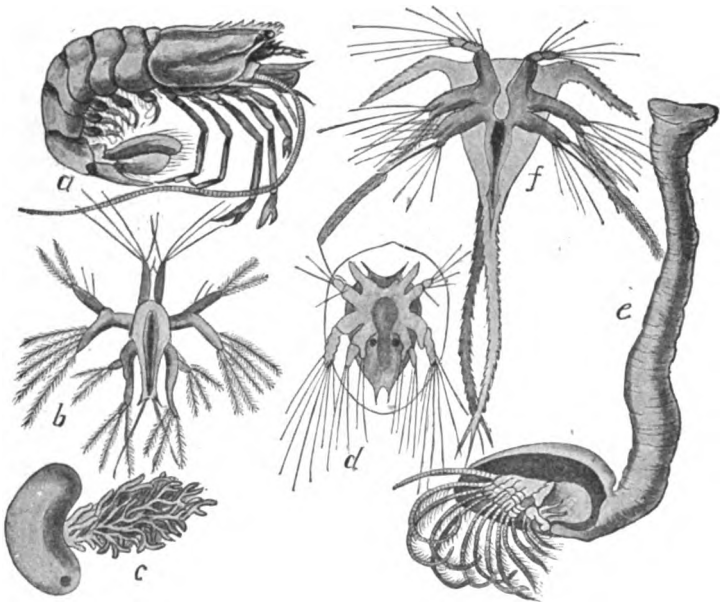


FIG. 123.—Three adult crustaceans and their larvæ. *a*, prawn (*Peneus*), active and free-living; *b*, larva of prawn; *c*, *Sacculina*, parasite; *d*, larva of *Sacculina*; *e*, barnacle (*Lepas*), with fixed quiescent life; *f*, larva of barnacle.—After HÆCKEL.

Certain insects live sedentary or fixed lives. All the members of the family of scale insects (Coccidæ), in one sex at least, show degeneration, that has been caused by quiescence. One of these coccids, called the red orange scale (Fig. 124), is very abundant in Florida and California and in other orange-growing regions. The male is a beautiful, tiny, two-winged midge, but the female is a wingless,

footless little sac without eyes or other organs of special sense, which lies motionless under a flat, thin, circular, reddish scale composed of wax and two or three cast skins of the insect itself. The insect has a long, slender, flexible, sucking beak, which is thrust into the leaf or stem or fruit of the orange on which the "scale bug" lives and through which the insect sucks the orange sap, which is its only

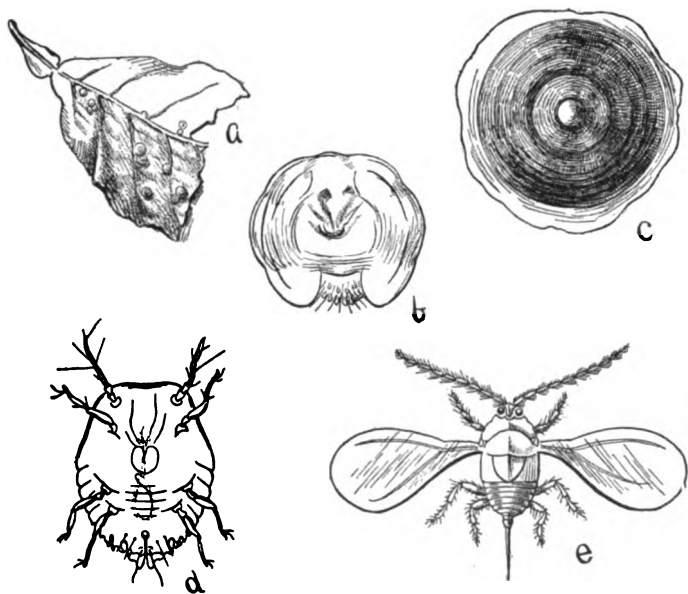


FIG. 124.—The red orange scale of California. *a*, bit of leaf with scales; *b*, adult female; *c*, wax scale under which adult female lives; *d*, larva; *e*, adult male.

food. It lays eggs under its body, and thus also under the protecting wax scale, and dies. From the eggs hatch active little larval scale-bugs with eyes and feelers and six legs. They crawl from under the wax scale and roam about over the orange tree. Finally, they settle down, thrusting their sucking beak into the plant tissues, and cast their skin. The females lose at this molt their legs and eyes and

feelers. Each becomes a mere motionless sac capable only of sucking up sap and of laying eggs. The young males, however, lose their sucking beak and can no longer take food, but they gain a pair of wings and an additional pair of eyes. They fly about and fertilize the sac-like females, which then molt again and secrete the thin wax scale over them.

Throughout the animal kingdom loss of the need of movement is followed by the loss of the power to move, and of all structures related to it.

103. Degeneration through other causes.—Loss of certain organs may occur through other causes than parasitism and a fixed life. Many insects live but a short time in their adult stage. May-flies live for but a few hours or, at most, a few days. They do not need to take food to sustain life for so short a time, and so their mouth parts have become rudimentary and functionless or are entirely lost. This is true of some moths and numerous other specially short-lived insects. Among the social insects the workers of the termites and of the true ants are wingless, although they are born of winged parents, and are descendants of winged ancestors. The modification of structure dependent upon the division of labor among the individuals of the community has taken the form, in the case of the workers, of a degeneration in the loss of the wings. Insects that live in caves are mostly blind; they have lost the eyes, whose function could not be exercised in the darkness of the cave. Certain island-inhabiting insects have lost their wings, flight being attended with too much danger. The strong sea-breezes may at any time carry a flying insect off the small island to sea. Only those which do not fly much survive, and by natural selection wingless breeds or species are produced. Finally, we may mention the great modifications of structure, often resulting in the loss of certain organs, which take place to produce protective resemblances (see Chapter XII). In such cases the body may be modified in

color and shape so as to resemble some part of the environment, and thus the animal may be unperceived by its enemies. Many insects have lost their wings through this cause.

104. Immediate causes of degeneration.—When we say that a parasitic or quiescent mode of life leads to or causes degeneration, we have explained the stimulus or the ultimate cause of degenerative changes, but we have not shown just how parasitism or quiescence actually produces these changes. Degeneration or the atrophy and disappearance of organs or parts of a body is often said to be due to disuse. That is, the disuse of a part is believed by many naturalists to be the sufficient cause for its gradual dwindling and final loss. That disuse can so affect parts of a body during the lifetime of an individual is true. A muscle unused becomes soft and flabby and small. Whether the effects of such disuse can be inherited, however, is open to serious doubt. Such inheritance must be assumed if disuse is to account for the gradual growing less and final disappearance of an organ in the course of many generations. Some naturalists believe that the results of such disuse can be inherited, but as yet such belief rests on no certain knowledge. If characters assumed during the lifetime of the individual are subject to inheritance, disuse alone may explain degeneration. If not, some other immediate cause, or some other cause along with disuse, must be found. Such a cause must be sought for in the action of natural selection, preserving the advantages of simplicity of structure where action is not required.

105. Advantages and disadvantages of parasitism and degeneration.—We are accustomed, perhaps, to think of degeneration as necessarily implying a disadvantage in life. A degenerate animal is considered to be not the equal of a non-degenerate animal, and this would be true if both kinds of animals had to face the same conditions of life. The blind, footless, simple, degenerate animal could not cope with the

active, keen-sighted, highly organized non-degenerate in free competition. But free competition is exactly what the degenerate animal has nothing to do with. Certainly the *Sacculina* lives successfully; it is well adapted for its own peculiar kind of life. For the life of a scale insect, no better type of structure could be devised. A parasite enjoys certain obvious advantages in life, and even extreme degeneration is no drawback, but rather favors it in the advantageousness of its sheltered and easy life. As long as the host is successful in eluding its enemies and avoiding accident and injury, the parasite is safe. It needs to exercise no activity or vigilance of its own; its life is easy as long as its host lives. But the disadvantages of parasitism and degeneration are apparent also. The fate of the parasite is usually bound up with the fate of the host. When the enemy of the host crab prevails, the *Sacculina* goes down without a chance to struggle in its own defense. But far more important than the disadvantage in such particular or individual cases is the disadvantage of the fact that the parasite can not adapt itself in any considerable degree to new conditions. It has become so specialized, so greatly modified and changed to adapt itself to the one set of conditions under which it now lives; it has gone so far in its giving up of organs and body parts, that if present conditions should change and new ones come to exist, the parasite could not adapt itself to them. The independent, active animal with all its organs and all its functions intact, holds itself, one may say, ready and able to adapt itself to any new conditions of life which may gradually come into existence. The parasite has risked everything for the sake of a sure and easy life under the presently existing conditions. Change of conditions means its extinction.

106. **Human degeneration.**—It is not proposed in these pages to discuss the application of the laws of animal life to man. But each and every one extends upward, and can

be traced in the relation of men and society. Thus, among men as among animals, self-dependence favors complexity of power. Dependence, parasitism, quiescence favor degeneration. Degeneration means loss of complexity, the narrowing of the range of powers and capabilities. It is not necessarily a phase of disease or the precursor of death. But as intellectual and moral excellence are matters associated with high development in man, dependence is unfavorable to them.

Degeneration has been called animal pauperism. Pauperism in all its forms, whether due to idleness, pampering, or misery, is human degeneration. It has been shown that a large part of the criminality and pauperism among men is hereditary, due to the survival of the tendency toward living at the expense of others. The tendency to live without self-activity passes from generation to generation. Beggary is more profitable than unskilled and inefficient labor, and our ways of careless charity tend to propagate the beggar. That form of charity which does not render its recipient self-helpful is an incentive toward degeneration. Withdrawal from the competition of life, withdrawal from self-helpful activity, aided by the voluntary or involuntary assistance of others—these factors bring about degeneration. The same results follow in all ages and with all races, with the lower animals as with men.

CHAPTER XII

PROTECTIVE RESEMBLANCES, AND MIMIORY

107. **Protective resemblance defined.**—If a grasshopper be startled from the ground, you may watch it and determine exactly where it alights after its leap or flight, and yet, on going to the spot, be wholly unable to find it. The colors and marking of the insect so harmonize with its surroundings of soil and vegetation that it is nearly indistinguishable as long as it remains at rest. And if you were intent on capturing grasshoppers for fish-bait, this resemblance in appearance to their surroundings would be very annoying to you, while it would be a great advantage to the grasshoppers, protecting some of them from capture and death. This is *protective resemblance*. Mere casual observation reveals to us that such instances of protective resemblance are very common among animals. A rabbit or grouse crouching close to the ground and remaining motionless is almost indistinguishable. Green caterpillars lying outstretched along green grass-blades or on green leaves may be touched before being recognized by sight. In arctic regions of perpetual snow the polar bears, the snowy arctic foxes, and the hares are all pure white instead of brown and red and gray like their cousins of temperate and warm regions. Animals of the desert are almost without exception obscurely mottled with gray and sand color, so as to harmonize with their surroundings.

In the struggle for existence anything that may give an animal an advantage, however slight, may be sufficient to turn the scale in favor of the organism possessing the

advantage. Such an advantage may be swiftness of movement, or unusual strength or capacity to withstand unfavorable meteorological conditions, or the possession of such color and markings or peculiar shape as tend to conceal the animal from its enemies or from its prey. Resemblances may serve the purpose of aggression as well as protection. In the case of the polar bears and other predaceous animals that show color likenesses to their surroundings, the resemblance can better be called aggressive than protective. The concealment afforded by the resemblance allows them to steal unperceived on their prey. This, of course, is an advantage to them as truly as escape from enemies would be.

We have already seen that by the action of natural selection and heredity those variations or conditions that give animals advantages in the struggle for life are preserved and emphasized. And so it has come about that advantageous protective resemblances are very widespread among animals, and assume in many cases extraordinarily striking and interesting forms. In fact, the explanation of much of the coloring and patterning of animals depends on this principle of protective resemblance.

Before considering further the general conditions of protective resemblances, it will be advisable to refer to specific examples classified roughly into groups or special kinds of advantageous colorings and markings.

108. **General protective or aggressive resemblance.**—As examples of general protective resemblance—that is, a general color effect harmonizing with the usual surroundings and tending to hide or render indistinguishable the animal—may be mentioned the hue of the green parrots of the evergreen tropical forests; of the green tree-frogs and tree-snakes which live habitually in the green foliage; of the mottled gray and tawny lizards, birds, and small mammals of the deserts; and of the white hares and foxes and snowy owls and ptarmigans of the snow-covered arctic regions. Of the same nature is the slaty blue of the

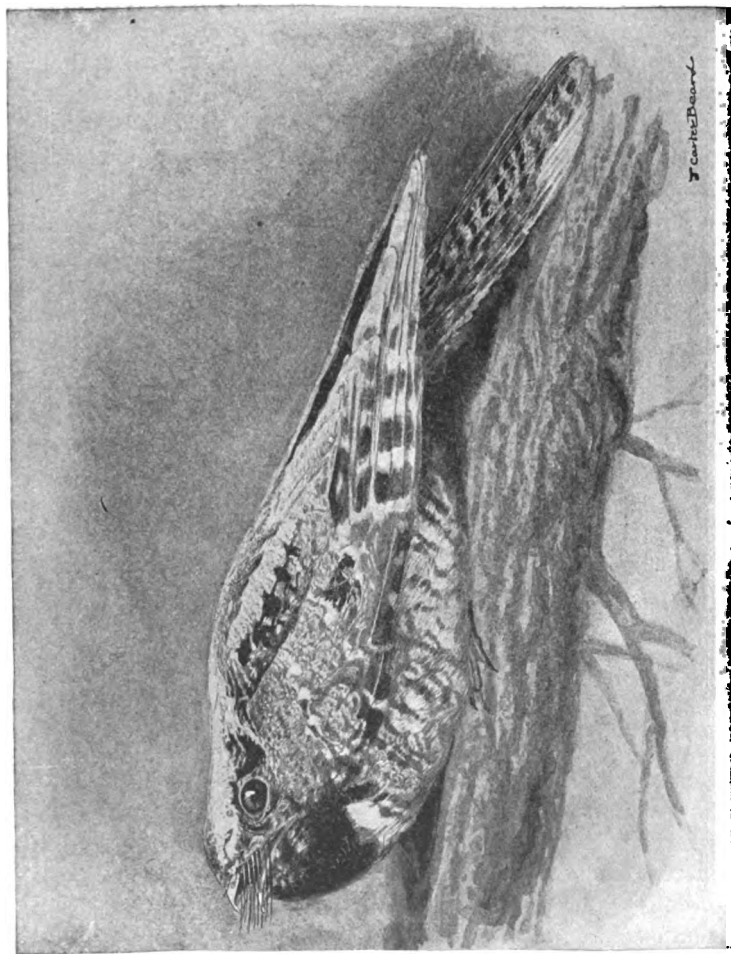


FIG. 125.—The whip-poor-will (*Antrostomus vociferans*), which is colored so as to harmonize with its usual surroundings when at rest.

gulls and terns, colored like the sea. In the brooks most fishes are dark olive or greenish above and white below. To the birds and other enemies which look down on them from above they are colored like the bottom. To their fish enemies which look up from below, their color is like the white light above them, and their forms are not clearly seen. The fishes of the deep sea in perpetual darkness are



FIG. 126.—Alligator lizard (*Gerrhonotus scincicauda*) on granite rock. Photograph by J. O. SNYDER, Stanford University, California.

inky violet in color below as well as above. Those that live among sea-weeds are red, grass-green, or olive, like the plants they frequent. General protective resemblance is very widespread among animals, and is not easily appreciated when the animal is seen in museums or zoölogical gardens—that is, away from its natural or normal environment. A modification of general color resemblance found in many animals may be called *variable* protective resemblance. Certain hares and other animals that live in northern latitudes are wholly white during the winter when the snow covers everything, but in summer, when much of the snow melts, revealing the brown and gray rocks and

withered leaves, these creatures change color, putting on a grayish and brownish coat of hair. The ptarmigan of the Rocky Mountains (one of the grouse), which lives on the snow and rocks of the high peaks, is almost wholly white in winter, but in summer when most of the snow is melted its plumage is chiefly brown. On the campus at Stanford University there is a little pond whose shores are covered in some places with bits of bluish rock, in other places with bits of reddish rock, and in still other places with sand. A small insect called the toad-bug (*Galgulus oculus*) lives abundantly on the banks of this pond. Specimens collected from the blue rocks are bluish in color, those from the red rocks are reddish, and those from the sand are sand-colored. Such changes of color to suit the changing surroundings can be quickly made in the case of some animals. The chameleons of the tropics, whose skin changes color momentarily from green to brown, blackish or golden, is an excellent example of this highly specialized condition. The same change is shown by a small lizard of our Southern States (*Anolis*), which from its habit is called the Florida chameleon. There is a little fish (*Oligocottus snyderi*) which is common in the tide pools of the bay of Monterey, in California, whose color changes quickly to harmonize with the different colors of the rocks it happens to rest above. Some of the tree-frogs show this variable coloring. A very striking instance of variable protective resemblance is shown by the chrysalids of certain butterflies. An eminent English naturalist collected many caterpillars of a certain species of



FIG. 127.—Chrysalid of swallow-tail butterfly (*Papilio*), harmonizing with the bark on which it rests.

butterfly, and put them, just as they were about to change into pupæ or chrysalids, into various boxes, lined with paper of different colors. The color of the chrysalid was found

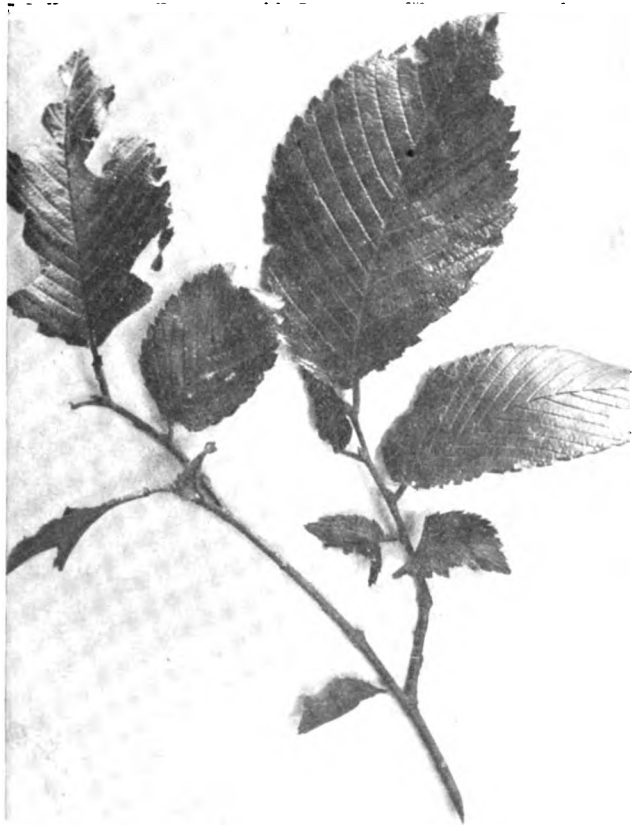


FIG. 128.—Chrysalid of butterfly (lower left-hand projection from stem), showing protective resemblance. Photograph from Nature.

to harmonize very plainly with the color of the lining of the box in which the chrysalid hung. It is a familiar fact to entomologists that most butterfly chrysalids resemble in

color and general external appearance the surface of the object on which they rest (Figs. 127 and 128).

109. **Special protective resemblance.**—Far more striking are those cases of protective resemblance in which the animal resembles in color and shape, sometimes in extraordinary detail, some particular object or part of its usual environment. Certain parts of the Atlantic Ocean are covered with great patches of sea-weed called the gulf-weed (*Sargassum*), and many kinds of animals—fishes and other creatures—live upon and among the algæ. No one can fail to note the extraordinary color resemblances which exist between those animals and the weed itself. The gulf-weed is of an olive-yellow color, and the crabs and shrimps, a certain flat-worm, a certain mollusk, and a little fish, all of which live among the *Sargassum*, are exactly of the same shade of yellow as the weed, and have small white markings on their bodies which are characteristic also of the *Sargassum*. The mouse-fish or *Sargassum* fish and the little sea-horses, often attached to the gulf-weed, show the same traits of coloration (Fig. 129). In the black rocks about Tahiti is found the black nokee or lava-fish (*Emmydrichthys vulcanus*) (Fig. 66), which corresponds perfectly in color and form to a piece of lava. This fish is also noteworthy for having envenomed spines in the fin on its back. The slender grass-green caterpillars of many moths and butterflies resemble very closely the thin grass-blades among which they live. The larvæ of the geometrid moths, called inch-worms or span-worms, are twig-like in appearance, and have the habit, when disturbed, of standing out stiffly from the twig or branch upon which they rest, so as to resemble in position as well as in color and markings a short or a broken twig. One of the most striking resemblances of this sort is shown by the large geometrid larva illustrated in Fig. 130, which was found near Ithaca, New York. The body of this caterpillar has a few small, irregular spots or humps, resembling very exactly the scars left by fallen



FIG. 129.—The mouse-fish (*Pterophryne histrio*) in the *Sargassum* or gulf-weed. The fishes are marked and colored so as to be nearly indistinguishable from the masses of the gulf-weed. In the lower right-hand corner of figure are two sea-horses, also shaped and marked so as to be concealed.

buds or twigs. These caterpillars have a special muscular development to enable them to hold themselves rigidly for



FIG. 130.—A geometrid larva on a branch. (The larva is the upper right-hand projection from the stem.)

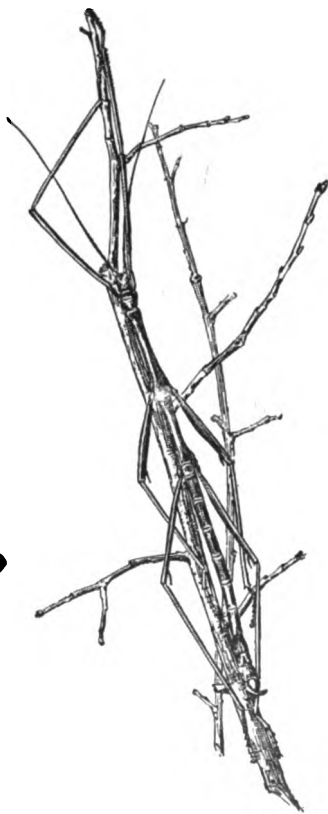


FIG. 131.—A walking-stick insect (*Diaperomera femorata*) on twig.

long times in this trying attitude. They also lack the middle prop-legs of the body, common to other lepidopter-

ous larvæ, the presence of which would tend to destroy the illusion so successfully carried out by them. The common walking-stick (*Diapheromera*) (Fig. 131), with its wingless, greatly elongate, dull-colored body, is an excellent example of special protective resemblance. It is quite indistinguishable, when at rest, from the twigs to which it is clinging. Another member of the family of insects to which the walking-stick belongs is the famous green-leaf insect (*Phyllium*)



FIG. 132.—The green-leaf insect (*Phyllium*).

(Fig. 132). It is found in South America and is of a bright green color, with broad leaf-like wings and body, with markings which imitate the leaf veins, and small irregular yellowish spots which mimic decaying or stained or fungus-covered spots in the leaf.

There are many butterflies that resemble dead leaves. All our common meadow browns (*Grapta*), brown and reddish butterflies with ragged-edged wings, that appear in the autumn and flutter aimlessly about exactly like the falling leaves, show this resemblance. But most remarkable of all is a

large butterfly (*Kallima*) (Fig. 133) of the East Indian region. The upper sides of the wings are dark, with purplish and orange markings, not at all resembling a dead leaf. But the butterflies when at rest hold their wings together over the back, so that only the under sides of the wings are exposed. The under sides of *Kallima's* wings are exactly the color of a dead and dried leaf, and

the wings are so held that all combine to mimic with extraordinary fidelity a dead leaf still attached to the twig by a short pedicle or leaf-stalk imitated by a short tail on the



FIG. 133.—*Kallima*, the "dead-leaf butterfly."

hind wings, and showing midrib, oblique veins, and, most remarkable of all, two apparent holes, like those made in leaves by insects, but in the butterfly imitated by two small circular spots free from scales and hence clear and trans-

parent. With the head and feelers concealed beneath the wings, it makes the resemblance wonderfully exact.

There are numerous instances of special protective resemblance among spiders. Many spiders (Fig. 134) that

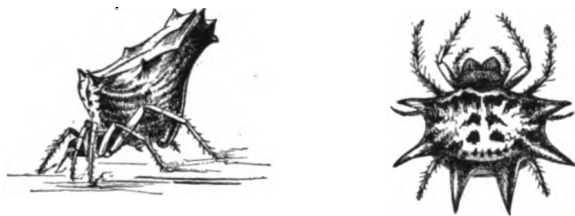


FIG. 134.—Spiders showing unusual shapes and patterns, for purposes of aggressive resemblance.

live habitually on tree trunks resemble bits of bark or small, irregular masses of lichen. A whole family of spiders, which live in flower-cups lying in wait for insects, are white and pink and party-colored, resembling the markings of the special flowers frequented by them. This is, of course, a



FIG. 135.—A pipe-fish (*Phyllopteryx*) resembling sea-weed, in which it lives.

special resemblance not so much for protection as for aggression; the insects coming to visit the flowers are unable to distinguish the spiders and fall an easy prey to them. /

110. **Warning colors and terrifying appearances.**—In the cases of advantageous coloring and patterning so far dis-

cussed the advantage to the animal lies in the resemblance between the animals and their surroundings, in the inconspicuousness and concealment afforded by the coloration. But there is another interesting phase of advantageous coloration in which the advantage derived is in rendering the animals as conspicuous and as readily recognizable as possible. While many animals are very inconspicuously colored, or are manifestly colored so as to resemble their surroundings, generally or specifically, many other animals are very brightly and conspicuously colored and patterned. If we are struck by the numerous cases of imitative coloring among insects, we must be no less impressed by the many cases of bizarre and conspicuous coloration among them.

Many animals, as we well know, possess special and effective weapons of defense, as the poison-fangs of the venomous snakes and the stings of bees and wasps. Other animals, and with these cases most of us are not so well acquainted, possess a means of defense, or rather safety, in being inedible—that is, in possessing some acrid or ill-tasting substance in the body which renders them unpalatable to predaceous animals. Many caterpillars have been found, by observation in Nature and by experiment, to be distasteful to insectivorous birds. Now, it is obvious that it would be a great advantage to these caterpillars if they could be readily recognized by birds, for a severe stroke by a bird's bill is about as fatal to a caterpillar as being wholly eaten. Its soft, distended body suffers mortal hurt if cut or bitten by the bird's beak. This advantage of being readily recognizable is possessed by many if not all ill-tasting caterpillars by being brilliantly and conspicuously colored and marked. Such colors and markings are called warning colors. They are intended to inform birds of the fact that the caterpillar displaying them is an ill-tasting insect, a caterpillar to be let alone. The conspicuously black-and-yellow banded larva (Fig. 43, *b*) of the common

Monarch butterfly is a good example of the possession of warning colors by distasteful caterpillars.

These warning colors are possessed not only by the ill-tasting caterpillars, but by many animals which have special means of defense. The wasps and bees, provided with stings—dangerous animals to trouble—are almost all conspicuously marked with yellow and black. The lady-bird beetles (Fig. 136), composing a whole family of small beetles

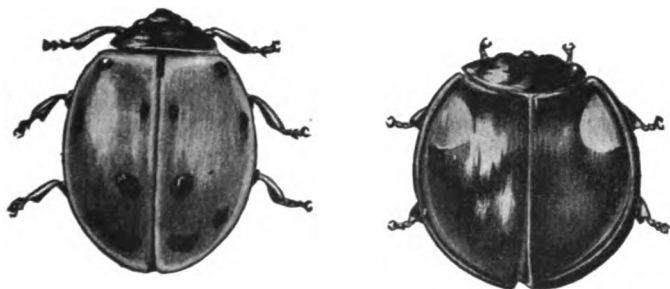


FIG. 136.—Two lady-bird beetles, conspicuously colored and marked.

which are all ill-tasting, are brightly and conspicuously colored and spotted. The Gila monster (*Heloderma*), the only poisonous lizard, differs from most other lizards in being strikingly patterned with black and brown. Some of the venomous snakes are conspicuously colored, as the coral snakes (*Elaps*) or coralillos of the tropics. The naturalist Belt, whose observations in Nicaragua have added much to our knowledge of tropical animals, describes as follows an interesting example of warning colors in a species of frog: "In the woods around Santo Domingo (Nicaragua) there are many frogs. Some are green or brown and imitate green or dead leaves, and live among foliage. Others are dull earth-colored, and hide in holes or under logs. All these come out only at night to feed, and they are all preyed upon by snakes and birds. In contrast with these obscurely colored species, another little frog hops about in

the daytime, dressed in a bright livery of red and blue. He can not be mistaken for any other, and his flaming breast and blue stockings show that he does not court concealment. He is very abundant in the damp woods, and I was convinced he was uneatable so soon as I made his acquaintance and saw the happy sense of security with which he hopped about. I took a few specimens home with me, and tried my fowls and ducks with them, but none would touch them. At last, by throwing down pieces of meat, for which there was a great competition among them, I managed to entice a young duck into snatching up one of the little frogs. Instead of swallowing it, however, it instantly threw it out of its mouth, and went about jerking its head, as if trying to throw off some unpleasant taste."

Certain animals which are without special means of defense and are not at all formidable or dangerous are yet so marked or shaped and so behave as to present a threatening or terrifying appearance. The large green caterpillars (Fig. 137) of the Sphinx moths—the tomato-worm is a familiar one of these larvæ—have a formidable-looking,

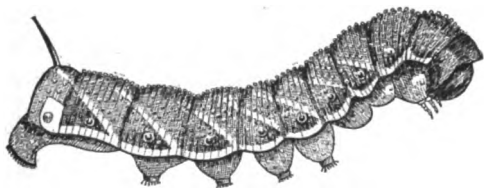


FIG. 137.—A "tomato-worm" larva of the Sphinx moth, *Phlegethonius carolina*, showing terrifying appearance.

sharp horn on the back of the next to last body ring. When disturbed they lift the hinder part of the body, bearing the horn, and move it about threateningly. As a matter of fact, the horn is not at all a weapon of defense, but is quite harmless. Numerous insects when disturbed lift the hind part of the body, and by making threatening mo-

tions lead enemies to believe that they possess a sting. The striking eye-spots of many insects are believed by some entomologists to be of the nature of terrifying appearances. The larva (Fig. 138) of the Puss moth (*Cerura*) has been often referred to as a striking example of terrifying appearances. When one of these larvæ is disturbed, "it retracts

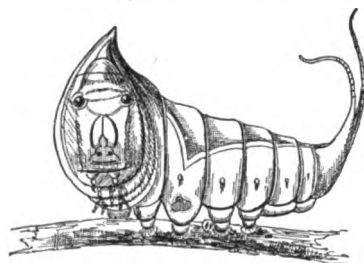
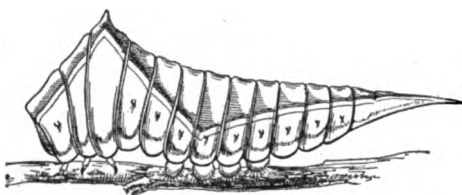


FIG. 138.—Larva of the Puss moth (*Cerura*). Upper figure shows the larva as it appears when undisturbed; lower figure, when disturbed.—After POULTON.

its head into the first body ring inflating the margin, which is of a bright red color. There are two intensely blackspots

on this margin in the appropriate position for eyes, and the whole appearance is that of a large flat face extending to the outer edge of the red margin. The effect is an intensely exaggerated caricature of a vertebrate face, which is probably alarming to the vertebrate enemies of the cat-

terpillar. . . . The effect is also greatly strengthened by two pink whips which are swiftly protruded from the prongs of the fork in which the body terminates. . . . The end of the body is at the same time curved forward over the back, so that the pink filaments are brandished above the head."

111. Alluring coloration.—A few animals show what are called alluring colors—that is, they display a color pattern so arranged as to resemble or mimic a flower or other lure, and thus to entice to them other animals, their natural prey. This is a special kind of aggressive resemblance. A species

of predatory insect called a "praying-horse" (allied to the genus *Mantis*), found in India, has the shape and color of an orchid. Small insects are attracted and fall a prey to it. Certain Brazilian fly-catching birds have a brilliantly colored crest which can be displayed in the shape of a flower-cup. The insects attracted by the apparent flower furnish the fly-catcher with food. An Asiatic lizard is wholly colored like the sand upon which it lives except for a peculiar red fold of skin at each angle of the mouth. This fold is arranged in flower-like shape, "exactly resembling a little red flower which grows in the sand." Insects attracted by these flowers find out their mistake too late. In the tribe of fishes called the "anglers" or fishing frogs the front rays of the dorsal fin are prolonged in shape of long, slender filaments, the foremost and longest of which has a flattened and divided extremity like the bait on a hook. The fish conceals itself in the mud or in the cavities of a coral reef and waves the filaments back and forth. Small fish are attracted by the lure, mistaking it for worms writhing about in the water or among the weeds. As they approach they are engulfed in the mouth of the angler, which in some of the species is of enormous size. One of these species is known to fishermen as the "all-mouth." These fishes (*Lophius piscatorius*), which live in the mud, are colored like mud or clay. Other forms of anglers, living among coral reefs, are brown and red (*Antennarius*), their coloration imitating in minutest detail the markings and outgrowths on the reef itself, the lure itself imitating a worm of the reef. In a certain group of deep-sea anglers, the sea-devils (*Ceratiidæ*), certain species show a still further specialization of the curious fishing-rod. In one species (*Corynolophus reinhardti*) (Fig. 54), living off the coast of Greenland at a depth of upward of a mile, the fishing-rod or first dorsal spine has a luminous bulb at its tip around which are fleshy, worm-like streamers. At the abyssal depths of a mile, more or less, frequented by these sea-

devils there is no light, the inky darkness being absolute. This shining lure is therefore a most effective means of securing food.

112. **Mimicry.**—Although the word mimicry could often have been used aptly in the foregoing account of protective resemblances, it has been reserved for use in connection with a certain specific group of cases. It has been reserved to be applied exclusively to those rather numerous instances where an otherwise defenseless animal, one without poison-fangs or sting, and without an ill-tasting substance in its body, mimics some other specially defended or inedible animal sufficiently to be mistaken for it and so to escape attack. Such cases of protective resemblance are called true mimicry, and they are especially to be observed among insects.

In Fig. 139 are pictured three familiar American butterflies. One of these, the Monarch butterfly (*Anosia plexippus*), is perhaps the most abundant and widespread butterfly of our country. It is a fact well known to entomologists that the Monarch is distasteful to birds and is let alone by them. It is a conspicuous butterfly, being large and chiefly of a red-brown color. The Viceroy butterfly (*Basilarchia archippus*), also red-brown and much like the Monarch, is not, as its appearance would seem to indicate, a very near relative of the Monarch, belonging to the same genus, but on the contrary it belongs to the same genus with the third butterfly figured, the black and white *Basilarchia*. All the butterflies of the genus *Basilarchia* are black and white except this species, the Viceroy, and one other. The Viceroy is not distasteful to birds; it is edible, but it mimics the inedible Monarch so closely that the deception is not detected by the birds, and so it is not molested.

In the tropics there have been discovered numerous similar instances of mimicry by edible butterflies of inedible kinds. The members of two great families of butterflies (*Danaidæ* and *Heliconidæ*) are distasteful to birds, and are

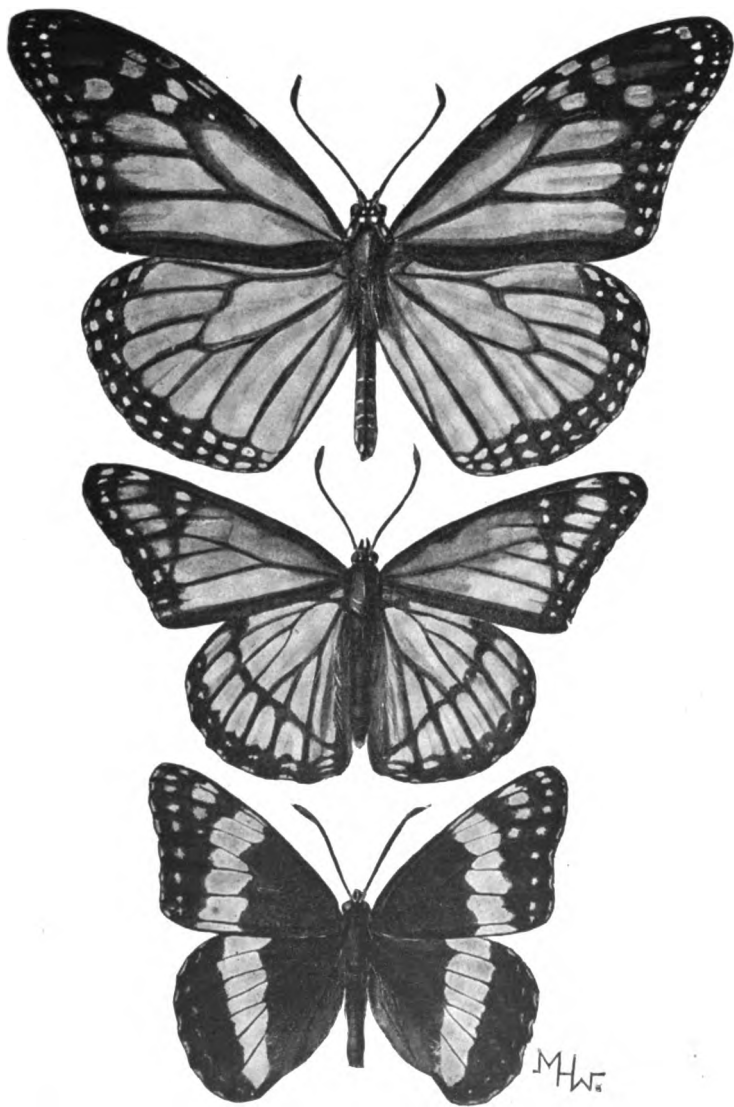


FIG. 139.—The mimicking of the inedible Monarch butterfly by the edible Viceroy. Upper figure is the Monarch (*Anosia plexippus*); middle figure is the Viceroy (*Basilarchia archippus*); lowest figure is another member of the same genus (*Basilarchia*), to show the usual color pattern of the species of the genus.

mimicked by members of the other butterfly families (especially the Pieridæ), to which family our common white cabbage-butterfly belongs, and by the swallow-tails (Papilionidæ).

The bees and wasps are protected by their stings. They are usually conspicuous, being banded with yellow and black. They are mimicked by numerous other insects, especially moths and flies, two defenseless kinds of insects. This mimicking of bees and wasps by flies is very common, and can be observed readily at any flowering shrub. The flower-flies (Syrphidæ), which, with the bees, visit flowers, can be distinguished from the bees only by sharp observing. When these bees and flies can be caught and examined in hand, it will be found that the flies have but two wings while the bees have four.

A remarkable and interesting case of mimicry among insects of different orders is that of certain South American tree-hoppers (of the family Membracidæ, of the order Hemiptera), which mimic the famous leaf-cutting ant (*Sauba*) of the Amazons (Fig. 140). These ants have the curious habit of cutting off, with their sharp jaws, bits of

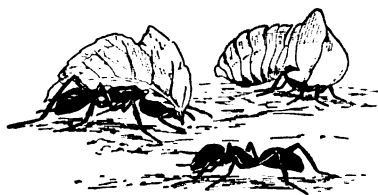


FIG. 140.—Tree-hopper (Membracidæ), which mimics the leaf-cutting ant (*Sauba*) of Brazil. (Upper right-hand insect is the tree-hopper.)

green leaves and carry-
ing them to their nests.
In carrying the bits of
leaves the ants hold them
vertically above their
heads. The leaf-hoppers
mimic the ants and their
burdens with remarka-
ble exactitude by having
the back of the body ele-
vated in the form of a

thin, jagged-edged ridge no thicker than a leaf. This part of the body is green like the leaves, while the under part of the body and the legs are brown like the ants.

Some examples of mimicry among other animals than

insects are known, but not many. The conspicuously marked venomous coral-snake or coralillos (*Elaps*) is mimicked by certain non-venomous snakes called king-snakes (*Lampropeltis*, *Osceola*). The pattern of red and black bands surrounding the cylindrical body is perfectly imitated. But whether this is true mimicry brought about for purposes of protection may be doubted. Instances among birds have been described, and a single case has been recorded in the class of mammals. But it is among the insects that the best attested instances occur. The simple fact of the close resemblance of two widely related animals can not be taken to prove the existence of mimicry. Two animals may both come to resemble some particular part in their common environment and thus to resemble closely each other. Here we have simply two instances of special protective resemblance, and not an instance of mimicry. The student of zoölogy will do well to watch sharply for examples of protective resemblance or mimicry, for but few of the instances that undoubtedly exist are as yet known.

113. Protective resemblances and mimicry most common among insects.—The large majority of the preceding examples have been taken from among the insects. This is explained by the fact that the phenomena of protective resemblances and mimicry have been studied especially among insects; the theory of mimicry was worked out chiefly from the observation and study of the colors and markings of insects and of the economy of insect life. Why protective resemblances and mimicry among insects have been chiefly studied is because these conditions are specially common among insects. The great class Insecta includes more than two thirds of all the known living species of animals. The struggle for existence among the insects is especially severe and bitter. All kinds of "shifts for a living" are pushed to extremes; and as insect colors and patterns are especially varied and conspicuous, it is

only to be expected that this useful modification of colors and patterns, that results in the striking phenomena of special protective resemblances and mimicry, should be specially widespread and pronounced among insects. Moreover, they are mostly deficient in other means of defense, and seem to be the favorite food for many different kinds of animals. Protective resemblance is their best and most widely adopted means of preserving life.

114. **No volition in mimicry.**—The use of the word mimicry has been criticised because it suggests the exercise of volition or intent on the part of the mimicking animal. The student should not entertain this conception of mimicry. In the use of “mimicry” in connection with the phenomena just described, the biologist ascribes to it a technical meaning, which excludes any suggestion of volition or intent on the part of the mimic. Just how such extraordinary and perfect cases of mimicry as shown by *Phyllium* and *Kallima* have come to exist is a problem whose solution is not agreed on by naturalists, but none of them makes volition—the will or intent of the animal—any part of his proposed solution. Each case of mimicry is the result of a slow and gradual change, through a long series of ancestors. The mimicry may indeed include the adoption of certain habits of action which strengthen and make more pronounced the deception of shape and color. But these habits, too, are the result of a long development, and are instinctive or reflex—that is, performed without the exercise of volition or reason.

115. **Color; its utility and beauty.**—The causes of color, and the uses of color in animals and in plants are subjects to which naturalists have paid and are paying much attention. The subject of “protective resemblances and mimicry” is only one, though one of the most interesting, branches or subordinate subjects of the general theory of the uses of color. Other uses are obvious. Bright colors and markings may serve for the attraction of mates; thus

are explained by some naturalists the brilliant plumage of the male birds, as in the case of the bird-of-paradise and the pheasants. Or they may serve for recognition characters, enabling the individuals of a band of animals readily to recognize their companions; the conspicuous whiteness of the short tail of the antelopes and cotton-tail rabbits, the black tail of the black-tail deer, and the white tail-feathers of the meadow-lark, are explained by many naturalists on this ground. Recognition marks of this type are especially numerous among the birds, hardly a species being without one or more of them, if their meaning is correctly interpreted. The white color of arctic animals may be useful not alone in rendering them inconspicuous, but may serve also a direct physiological function in preventing the loss of heat from the body by radiation. And the dark colors of animals may be of value to them in absorbing heat rays and thus helping them to keep warm. But "by far the most widespread use of color is to assist an animal in escaping from its enemies or in capturing its prey."

The colors of an animal may indeed not be useful to it at all. Many color patterns exist on present-day birds simply because, preserved by heredity, they are handed down by their ancestors, to whom, under different conditions of life, they may have been of direct use. For the most part, however, we can look on the varied colors and the striking patterns exhibited by animals as being in some way or another of real use and value. We can enjoy the exquisite coloration of the wings of a butterfly none the less, however, because we know that these beautiful colors and their arrangement tend to preserve the life of the dainty creature, and have been produced by the operation of fixed laws of Nature working through the ages.

CHAPTER XIII

THE SPECIAL SENSES

116. Importance of the special senses.—The means by which animals become acquainted with the outer world are the special senses, such as feeling, tasting, smelling, hearing, and seeing. The behavior of animals with regard to their surroundings, with regard to all the world outside of their own body, depends upon what they learn of this outer world through the exercise of these special senses. Habits are formed on the basis of experience or knowledge of the outer world gained by the special senses, and the development of the power to reason or to have sense depends on their pre-existence.

117. Difficulty of the study of the special senses.—We are accustomed to think of the organs of the special senses as extremely complex parts of the body, and this is certainly true in the case of the higher animals. In our own body the ears and eyes are organs of most specialized and highly developed condition. But we must not overlook the fact that the animal kingdom is composed of creatures of widely varying degrees of organization, and that in any consideration of matters common to all animals those animals of simplest and most lowly organization must be studied as well as those of high development. The study of the special senses presents two phases, namely, the study of the structure of the organs of special sense, and the study of the physiology of special sense—that is, the functions of these organs. It will be recognized that in the study of how other animals feel and taste and smell and hear and

see, we shall have to base all our study on our own experience. We know of hearing and seeing only by what we know of our own hearing and seeing; but by examination of the structure of the hearing and seeing organs of certain other animals, and by observation and experiments, zoölogists are convinced that some animals hear sounds that we can not hear, and some see colors that we can not see.

While that phase of the study of the special senses which concerns their structure may be quite successfully undertaken, the physiological phase of the study of the actual tasting and seeing and hearing of the lower animals is a matter of much difficulty. The condition and character of the special senses vary notably among different animals. There may even exist other special senses than the ones we possess. Some zoölogists believe that certain marine animals possess a "density or pressure sense"—that is, a sense which enables them to tell approximately how deep in the water they may be at any time. To certain animals is ascribed a "temperature sense," and some zoölogists believe that what we call the homing instinct of animals as shown by the homing pigeons and honey-bees and other animals, depends on their possession of a special sense which man does not possess. Recent experiments, however, seem to show that the homing of pigeons depends on their keen sight. In numerous animals there exist, besides the organs of the five special senses which we possess, organs whose structure compels us to believe them to be organs of special sense, but whose function is wholly unknown to us. Thus in the study of the special senses we are made to see plainly that we can not rely simply on our knowledge of our own body structure for an understanding of the structure and functions of other animals.

118. **Special senses of the simplest animals.**—In the *Amoeba* (see Chapter I), that type of the simplest animals, with

one-celled body, without organs, and yet with its capacity for performing the necessary life processes, there are no special senses except one (perhaps two). The *Amœba* can feel. It possesses the tactile sense. And there are no special sense organs except one, which is the whole of the outer surface of the body. If the *Amœba* be touched with a fine point it feels the touch, for the soft viscous protoplasm of its body flows slowly away from the foreign object. The sense of feeling or touch, the tactile sense, is the simplest or most primitive of the special senses, and the simplest, most primitive organ of special sense is the outer surface or skin of the body. Among those simple animals that possess the simplest organs of hearing and perceiving light, we shall find these organs to be simply specialized parts of the skin or outer cell layer of the body, and it is a fact that all the special sense organs of all animals are derived or developed from the outer cell layer, ectoblast, of the embryo. This is true also of the whole nervous system, the brain and spinal cord of the vertebrates, and the ganglia and nerve commissures of the invertebrates. And while in the higher animals the nervous system lies underneath the surface of the body, in many of the lower, many-celled animals all the ganglia and nerves, all of the nervous system, lie on the outer surface of the body, being simply a specialized part of the skin.

119. **The sense of touch.**—In some of the lower, many-celled animals, as among the polyps, there are on the skin certain sense cells, either isolated or in small groups, which seem to be stimulated not alone by the touching of foreign substances, but also by warmth and light. They are not limited to a single special sense. They are the primitive or generalized organs of special sense, and can develop into specialized organs for any one of the special senses.

The simplest and most widespread of these special senses with, as a whole, the simplest organs, is the tactile

sense, or the sense of touch. The special organs of this sense are usually simple hairs or papillæ connecting with a nerve. These tactile hairs or papillæ may be distributed pretty evenly over most of the body, or may be mainly concentrated upon certain parts in crowded groups. Many of the lower animals have projecting parts, like the feeling tentacles of many marine invertebrates, or the antennæ (feelers) of crabs and insects, which are the special seat of the tactile organs. Among the vertebrates the tactile organs are either like those of the invertebrates, or are little sac-like bodies of connective tissue in which the end of a nerve is curiously folded and convoluted (Fig. 141). These little touch corpuscles simply lie in the cell layer of the skin, covered over thinly by the cuticle. Sometimes they are simply free, branched nerve-endings in the skin. These tactile corpuscles or free nerve-endings are especially abundant in those parts of the body which can be best used for feeling. In man the finger-tips are thus especially supplied; in certain tailed monkeys the tip of the tail, and in hogs the end of the snout. The difference in abundance of these tactile corpuscles of the skin can be readily shown by experiment. With a pair of compasses, whose points have been slightly blunted, touch the skin of the forearm of a

person who has his eyes shut, with the points about three inches apart and in the direction of the length of the arm. The person touched will feel the points as two. Repeat the touching several times, gradually lessening the distance between the points. When the points are not more than an inch to an inch and a half apart, the person touched will feel but a single touch—that is, the touching

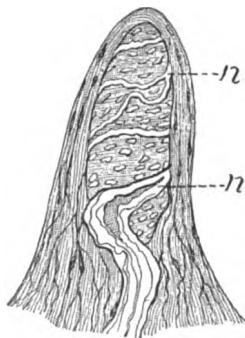


FIG. 141.—Tactile papilla of skin of man. n, nerve.—
After KOELLIKER.

of both points will give the sensation of but a single contact. Repeat the experiment on the tip of the forefinger, and both points will be felt until the points are only about one tenth of an inch apart.

120. **The sense of taste.**—The sense of taste enables us to test in some degree the chemical constitution of substances which are taken into the mouth as food. We discriminate by the taste organs between good food and bad, well-tasting and ill-tasting. These organs are, with us and the other air-breathing animals, located in the mouth or on the mouth parts. They must be located so as to come into contact with the food, and it is also necessary that the food substance to be tasted be made liquid. This is accomplished by the fluids poured into the mouth from the salivary glands. With the lower aquatic animals it is not improbable that taste organs are situated on other parts of the body besides the mouth, and that taste is used not only to test food substances, but also to test the chemical character of the fluid medium in which they live.

The taste organs are much like the tactile organs, except that the special taste cell is exposed, so that small particles of the substance to be tasted can come into actual contact with it. The nerve-ending is usually in a small raised papilla or depressed pit. In the simplest animals there is no special organ of taste, and yet *Amœba* and other Protozoa show that they appreciate the chemical constitution of the liquid in which they lie. They taste—that is, test the chemical constitution of the substances—by means of their undifferentiated body surface. The taste organs are not always to be told from the organs of smell. Where an animal has a certain special seat of smell, like the nose of the higher animals, then the special sense organs of the mouth can be fairly assumed to be taste organs; but where the seat of both smell and taste is in the mouth or mouth parts, it is often impossible to distinguish between the two kinds of organs.

In mammals taste organs are situated on certain parts of the tongue, and have the form of rather large, low, broad papillæ, each bearing many small taste-buds (Fig. 142). In fishes similar papillæ and buds have been found in various places on the surface of the body, from which it is believed that the sense of taste in fishes is not limited to the mouth. In insects the taste-papillæ and taste-pits are grouped in certain places on the mouth parts, being especially abundant on the tips of small, segmented, feeler-like processes called palpi, which project from the under lip and from the so-called maxillæ.

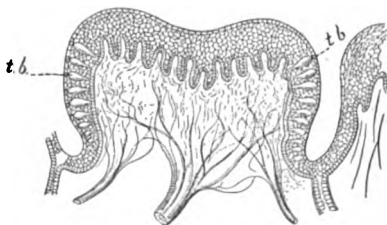


FIG. 142.—Vertical section of large papilla on tongue of a calf; *t.b.*, taste-buds. — After LOVÉN.

121. The sense of smell.—Smelling and tasting are closely allied, the one testing substances dissolved, the other testing substances vaporized. The organs of the sense of smell are, like those of taste, simple nerve-endings in papillæ or pits. The substance to be smelled must, however, be in a very finely divided form; it must come to the organs of smell as a gas or vapor, and not, as to the organs of taste, in liquid condition. The organs of smell are situated usually on the head, but as the sense of smell is used not alone for the testing of food, but for many other purposes, the organs of smell are not, like those of taste, situated principally in or near the mouth. Smell is a special sense of much wider range of use than taste. By smell animals can discover food, avoid enemies, and find their mates. They can test the air they breathe as well as the food they eat. In the matter of the testing of food the senses of both taste and smell are constantly used, and are indeed intimately associated.

The sense of smell varies a great deal in its degree of development in various animals. With the strictly aquatic animals—and these include most of the lower invertebrates, as the polyps, the star-fishes, sea-urchins, and most of the worms and mollusks—the sense of smell is probably but little developed. There is little opportunity for a gas or vapor to come to these animals, and only as a gas or vapor can a substance be smelled. With these animals the sense of taste must take the place of the olfactory sense. But among the insects, mostly terrestrial animals, there is an extraordinary development of the sense of smell. It is indeed probably their principal special sense. Insects must depend on smell far more than on sight or hearing for

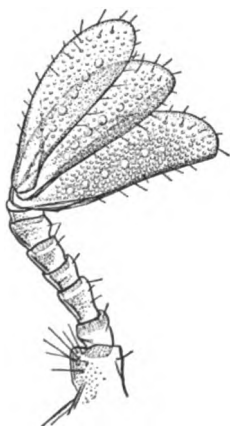


FIG. 143.—Antenna of a leaf-eating beetle, showing smelling-pits on the expanded terminal segments.

the discovery of food, for becoming aware of the presence of their enemies and of the proximity of their mates and companions. The organs of smell of insects are situated principally on the antennæ or feelers, a single pair of which is borne on the head of every insect (Fig. 143). That many insects have an extraordinarily keen sense of smell has been shown by numerous experiments, and is constantly proved by well-known habits. If a small bit of decaying flesh be inclosed in a box so that it is wholly concealed, it will nevertheless soon be found by the flies and carrion beetles that either feed on carrion or must always lay their eggs in de-

caying matter so that their carrion-eating larvæ may be provided with food. It is believed that ants find their way back to their nests by the sense of smell, and that they can recognize by scent among hundreds of individuals taken from various communities the members of their

own community. In the insectary at Cornell University, a few years ago, a few females of the beautiful promethea moth (*Callosamia promethea*) were inclosed in a box, which was kept inside the insectary building. No males had been seen about the insectary nor in its immediate vicinity, although they had been sought for by collectors. A few hours after the beginning of the captivity of the female moths there were forty male prometheas fluttering about over the glass roof of the insectary. They could not



FIG. 144.—Promethea moth, male, showing specialized antennæ.

see the females, and yet had discovered their presence in the building. The discovery was undoubtedly made by the sense of smell. These moths have very elaborately developed antennæ (Fig. 144), finely branched or feathered, affording opportunity for the existence of very many smelling-pits.

The keenness of scent of hounds and bird dogs is familiar to all, although ever a fresh source of astonishment as we watch these animals when hunting. We recently watched a retriever dog select unerringly, by the sense of smell, any particular duck out of a pile of a hundred. In

the case of man the sense of smell is not nearly so well developed as among many of the other vertebrates. This inferiority is largely due to degeneration through lessened need; for in Indians and primitive races the sense of smell is keener and better developed than in civilized races. Where man has to make his living by hunting, and has to avoid his enemies of jungle and plain, his special senses are better developed than where the necessity of protection and advantage by means of such keenness of scent and hearing is done away with by the arts of civilization.

122. **The sense of hearing.**—Hearing is the perception of certain vibrations of bodies. These vibrations give rise to waves—sound waves as they are called—which proceed from the vibrating body in all directions, and which, coming to an animal, stimulate the special auditory or hearing organs, that transmit this stimulation along the auditory nerve to the brain, where it is translated as sound. These sound waves come to animals usually through the air, or, in the case of aquatic animals, through water, or through both air and water.

The organs of hearing are of very complex structure in the case of man and the higher vertebrates. Our ears, which are adapted for perceiving or being stimulated by vibrations ranging from 16 to 40,000 a second—that is, for hearing all those sounds produced by vibrations of a rapidity not less than 16 to a second nor greater than 40,000 to a second—are of such complexity of structure that many pages would be required for their description. But among the lower or less highly organized animals the ears, or auditory organs, are much simpler.

In most animals the auditory organs show the common characteristic of being wholly composed of, or having as an essential part, a small sac filled with liquid in which one or more tiny spherical hard bodies called *otoliths* are held. This auditory sac is formed of or lined internally by

auditory cells, specialized nerve cells, which often bear delicate vibratile hairs (Fig. 145). Auditory organs of this general character are known among the polyps, the worms, the crustaceans, and the mollusks. In the common cray-fish the "ears" are situated in the basal segment of the inner antennæ or feelers (Fig. 146). They consist each of a small sac filled with liquid in which are suspended several grains of sand or other hard bodies. The inner

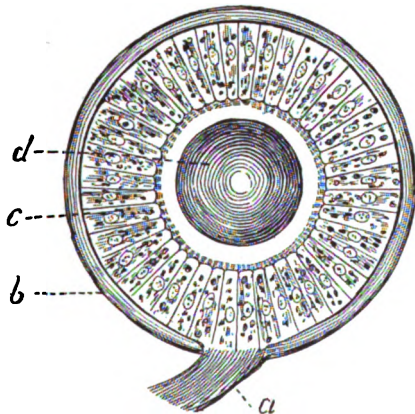


FIG. 145.—Auditory organ of a mollusk. *a*, auditory nerve; *b*, outer wall of connective tissue; *c*, cells with auditory hairs; *d*, otolith.—After LEYDIG.



FIG. 146.—Antenna of cray-fish, with auditory sac at base.—After HUXLEY.

surface of the sac is lined with fine auditory hairs. The sound waves coming through the air or water outside strike against this sac, which lies in a hollow on the upper or outer side of the antennæ. The sound waves are taken up by the contents of the sac and stimulate the fine hairs, which in turn give this stimulus to the nerves which run from them to the principal auditory nerve and thus to the brain of the cray-fish. Among the insects other kinds of auditory organs exist. The common locust or grasshopper

has on the upper surface of the first abdominal segment a pair of tympana or ear-drums (Fig. 147), composed simply of the thinned, tightly stretched chitinous cuticle of the body. On the inner surface of this

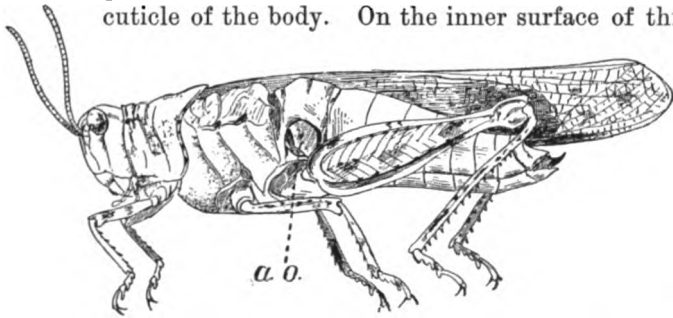


FIG. 147.—Grasshopper, showing auditory organ (*a. o.*) in first segment of abdomen. (Wings of one side removed.)

ear-drum there are a tiny auditory sac, a fine nerve leading from it to a small auditory ganglion lying near the tympanum, and a large nerve leading from this ganglion to one of the larger ganglia situated on the floor of the

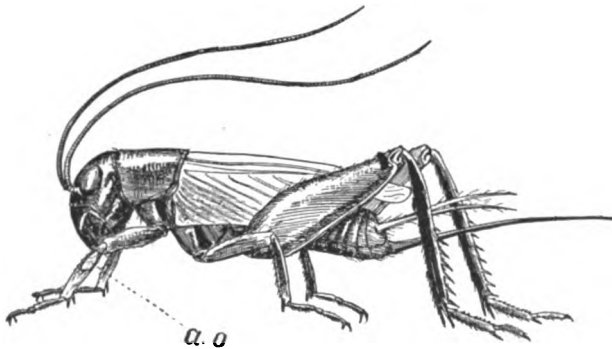


FIG. 148.—A cricket, showing auditory organ (*a. o.*) in fore-leg.

thorax. In the crickets and katydids, insects related to the locusts, the auditory organs or ears are situated in the fore-legs (Fig. 148).

Certain other insects, as the mosquitoes and other midges

or gnats, undoubtedly hear by means of numerous delicate hairs borne on the antennæ. The male mosquitoes (Fig. 149) have many hundreds of these long, fine antennal hairs, and on the sounding of a tuning-fork these hairs have been observed to vibrate strongly. In the base of each antenna there is a most elaborate organ, composed of fine chitinous rods, and accompanying nerves and nerve cells whose function it is to take up and transmit through the auditory nerve to the brain the stimuli received from the external auditory hairs.

123. Sound-making.—The sense of hearing enables animals not only to hear the warning natural sounds of storms and falling trees and plunging avalanches, but the sounds made by each other. Sound-making among animals serves to aid in frightening away enemies or in warning companions of their approach, for recognition among mates

and members of a band or species, for the attracting and wooing of mates, and for the interchange of information. With the cries and roars of mammals, the songs of birds, and the shrilling and calling of insects all of us are familiar. These are all sounds that can be heard by the human ear. But that there are many sounds made by animals that we can not hear—that is, that are of too high a pitch for our hearing organs to be stimulated by—is believed by naturalists. Especially is this almost certainly true in the case of the insects. The peculiar sound-producing organs of

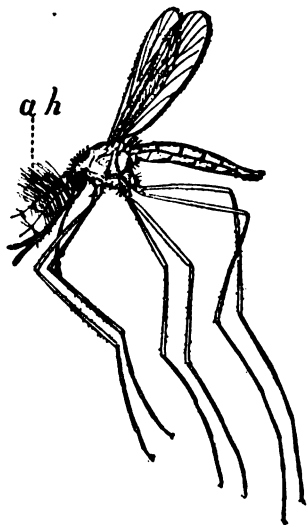


FIG. 149.—A male mosquito, showing auditory hairs (*a. h.*) on the antennæ.

many sound-making insects are known ; but certain other insects, which make no sound that we can hear, nevertheless possess similar sound-making organs.

Sound is produced by mammals and birds by the striking of the air which goes to and comes from the lungs against certain vibratory cords or flaps in the air-tubes. Sounds made by this vibration are re-enforced and made louder by arrangements of the air-tubes and mouth for resonance, and the character or quality of the sound is modified at will to a greater or less degree by the lips and teeth and other mouth structures. Sounds so made are said to be produced by a *voice*, or animals making sounds in this way are said to possess a voice. Animals possessing a voice have far more range and variety in their sound-making than most of the animals which produce sounds in other ways. The marvelous variety and the great strength of the singing of birds and of the cries and roars of mammals are unequaled by the sounds of any other animals.

But many animals without a voice—that is, which do not make sounds from the air-tubes—make sounds, and some of them, as certain insects, show much variety and range in their singing. The sounds of insects are made by the rapid vibrations of the wings, as the humming or buzzing of bees and flies, by the passage of air out or into the body through the many breathing pores or spiracles (a kind of voice), by the vibration of a stretched membrane or tympanum, as the loud shrilling of the cicada, and most commonly by stridulation—that is, by rubbing together two roughened parts of the body. The male crickets and the male katydids rub together the bases of their wing covers to produce their shrill singing. The locusts or grasshoppers make sounds when at rest by rubbing the roughened inside of their great leaping legs against the upper surface of their wing covers, and when in flight by striking the two wings of each side together. Numerous other insects make sounds by stridulation, but many of

these sounds are so feeble or so high in pitch that they are rarely heard by us. Certain butterflies make an odd clicking sound, as do some of the water-beetles. In Japan, where small things which are beautiful are prized not less than large ones, singing insects are kept in cages and highly valued, so that their capture becomes a lucrative industry, just as it is with song birds in Europe and America. Among the many species of Japanese singing insects is a night cricket, known as the bridle-bit insect, because its note resembles the jingling of a bridle-bit.

124. **The sense of sight.**—Not all animals have eyes. The moles which live underground, insects, and other animals that live in caves, and the deep-sea fishes which live in waters so deep that the light of the sun never comes to them, have no eyes at all, or have eyes of so rudimentary a character that they can no longer be used for seeing. But all these eyeless animals have no eyes because they live under conditions where eyes are useless. They have lost their eyes by degeneration. There are, however, many animals that have no eyes, nor have they or their ancestors ever had eyes. These are the simplest, most lowly organized animals. Many, perhaps all eyeless animals are, however, capable of distinguishing light from darkness. They are sensitive to light. An investigator placed several individuals of the common, tiny fresh-water polyp (*Hydra*) in a glass cylinder the walls of which were painted black. He left a small part of the cylinder unpainted, and in this part of the cylinder where the light penetrated the Hydras all gathered. The eyeless maggots or larvæ of flies, when placed in the light will wriggle and squirm away into dark crevices. They are conscious of light when exposed to it, and endeavor to shun it. Most plants turn their leaves toward the light; the sunflowers turn on their stems to face the sun. Light seems to stimulate organisms whether they have eyes or not, and the organisms either try to get into the light or to avoid it. But this is not seeing.

The simplest eyes, if we may call them eyes, are not capable of forming an image or picture of external objects. They only make the animal better capable of distinguishing between light and darkness or shadow. Many lowly organized animals, as some polyps, and worms, have certain cells of the skin specially provided with pigment. These cells grouped together form what is called a pigment fleck, which can, because of the presence of the pigment, absorb more light than the skin cells, and are more sensitive to the light. By such pigment-flecks, or eye-spots, the animal can detect, by their shadows, the passing near them of moving bodies, and thus be in some measure informed of the approach of enemies or of prey. Some of these eye-flecks are provided, not simply with pigment, but with a simple sort of lens that serves to concentrate rays of light and

make this simplest sort of eye even more sensitive to changes in the intensity of light (Fig. 150).

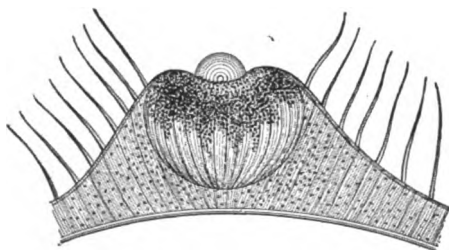


FIG. 150.—The simple eye of a jelly-fish (*Lizzia koellikeri*).—After O. and R. HERTWIG.

Most of the many-celled animals possess eyes by means of which a picture of exter-

nal objects more or less nearly complete and perfect can be formed. There is great variety in the finer structure of these picture-forming eyes, but each consists essentially of an inner delicate or sensitive nervous surface called the *retina*, which is stimulated by light, and is connected with the brain by a large *optic nerve*, and of a transparent light-refracting lens lying outside of the retina and exposed to the light. These are the constant essential parts of an image-forming and image-perceiving eye. In most eyes there are other accessory parts which may make the whole

eye an organ of excessively complicated structure and of remarkably perfect seeing capacity. Our own eyes are organs of extreme structural complexity and of high development, although some of the other vertebrates have undoubtedly a keener and more nearly perfected sight.

The crustaceans and insects have eyes of a peculiar character called compound eyes. In addition most insects have smaller simple eyes. Each of the compound eyes is composed of many (from a few, as in certain ants, to as many as twenty-five thousand, as in certain beetles) eye elements, each eye element seeing independently of the other eye elements and seeing only a very small part of any object in front of the whole eye. All these small parts of the external object seen by the many distinct eye elements are combined so as to form an image in mosaic—that is, made up of separate small parts—of the external object.

If the head of a dragon-fly be examined, it will be seen that two thirds or more of the

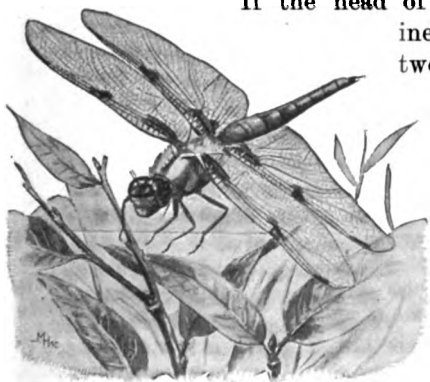


FIG. 151.—A dragon-fly, showing the large compound eyes on the head.

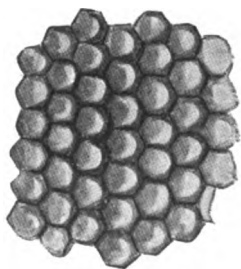


FIG. 152.—Some of the facets of the compound eye of a dragon-fly.

whole head is made up of the two large compound eyes (Fig. 151), and with a lens it may be seen that the outer surface of each of these eyes is composed of many small spaces or facets (Fig. 152) which are the outer lenses of the many eye elements composing the whole eye.

CHAPTER XIV

INSTINCT AND REASON

125. Irritability.—All animals of whatever degree of organization show in life the quality of irritability or response to external stimulus. Contact with external things produces some effect on each of them, and this effect is something more than the mere mechanical effect on the matter of which the animal is composed. In the one-celled animals the functions of response to external stimulus are not localized. They are the property of any part of the protoplasm of the body. Just as breathing or digestion is a function of the whole cell, so are sensation and response in action. In the higher or many-celled animals each of these functions is specialized and localized. A certain set of cells is set apart for each function, and each organ or series of cells is released from all functions save its own.

126. Nerve cells and fibers.—In the development of the individual animal certain cells from the primitive external layer or ectoblast of the embryo are set apart to preside over the relations of the creature to its environment. These cells are highly specialized, and while some of them are highly sensitive, others are adapted for carrying or transmitting the stimuli received by the sensitive cells, and still others have the function of receiving sense-impressions and of translating them into impulses of motion. The nerve cells are receivers of impressions. These are gathered together in nerve masses or ganglia, the largest of these being known as the brain, the ganglia in general being known as nerve centers. The nerves are of two classes.

The one class, called sensory nerves, extends from the skin or other organ of sensation to the nerve center. The nerves of the other class, motor nerves, carry impulses to motion.

127. **The brain or sensorium.**—The brain or other nerve center sits in darkness surrounded by a bony protecting box. To this main nerve center, or *sensorium*, come the nerves from all parts of the body that have sensation, the external skin as well as the special organs of sight, hearing, taste, smell. With these come nerves bearing sensations of pain, temperature, muscular effort—all kinds of sensation which the brain can receive. These nerves are the sole sources of knowledge to any animal organism. Whatever idea its brain may contain must be built up through these nerve impressions. The aggregate of these impressions constitute the world as the organism knows it. All sensation is related to action. If an organism is not to act, it can not feel, and the intensity of its feeling is related to its power to act.

128. **Reflex action.**—These impressions brought to the brain by the sensory nerves represent in some degree the facts in the animal's environment. They teach something as to its food or its safety. The power of locomotion is characteristic of animals. If they move, their actions must depend on the indications carried to the nerve center from the outside; if they feed on living organisms, they must seek their food; if, as in many cases, other living organisms prey on them, they must bestir themselves to escape. The impulse of hunger on the one hand and of fear on the other are elemental. The sensorium receives an impression that food exists in a certain direction. At once an impulse to motion is sent out from it to the muscles necessary to move the body in that direction. In the higher animals these movements are more rapid and more exact. This is because organs of sense, muscles, nerve fibers, and nerve cells are all alike highly specialized. In the star-fish the sensation is slow, the muscular response sluggish, but the

method remains the same. This is simple reflex action, an impulse from the environment carried to the brain and then unconsciously reflected back as motion. The impulse of fear is of the same nature. Strike at a dog with a whip, and he will instinctively shrink away, perhaps with a cry. Perhaps he will leap at you, and you unconsciously will try to escape from him. Reflex action is in general unconscious, but with animals as with man it shades by degrees into conscious action, and into volition or action "done on purpose."

129. **Instinct.**—Different one-celled animals show differences in method or degree of response to external influences. The feelers of the *Amæba* will avoid contact with the feelers or pseudopodia of another *Amæba*, while it does not shrink from contact with itself or with an organism of unlike kind on which it may feed. Most Protozoa will discard grains of sand, crystals of acid, or other indigestible object. Such peculiarities of different forms of life constitute the basis of instinct.

Instinct is automatic obedience to the demands of external conditions. As these conditions vary with each kind of animal, so must the demands vary, and from this arises the great variety actually seen in the instincts of different animals. As the demands of life become complex, so may the instincts become so. The greater the stress of environment, the more perfect the automatism, for impulses to safe action are necessarily adequate to the duty they have to perform. If the instinct were inadequate, the species would have become extinct. The fact that its individuals persist shows that they are provided with the instincts necessary to that end. Instinct differs from other allied forms of response to external condition in being hereditary, continuous from generation to generation. This sufficiently distinguishes it from reason, but the line between instinct and reason and other forms of reflex action can not be sharply drawn.

It is not necessary to consider here the question of the origin of instincts. Some writers regard them as "inherited habits," while others, with apparent justice, doubt if mere habits or voluntary actions repeated till they become a "second nature" ever leave a trace upon heredity. Such investigators regard instinct as the natural survival of those methods of automatic response which were most useful to the life of the animal, the individuals having less effective methods of reflex action having perished, leaving no posterity.

An example in point would be the homing instinct of the fur-seal. When the arctic winter descends on its home in the Pribilof Islands in Bering Sea, these animals take to the open ocean, many of them swimming southward as far as the Santa Barbara Islands in California, more than three thousand miles from home. While on the long swim they never go on shore, but in the spring they return to the northward, finding the little islands hidden in the arctic fogs, often landing on the very spot from which they were driven by the ice six months before, and their arrival timed from year to year almost to the same day. The perfection of this homing instinct is vital to their life. If defective in any individual, he would be lost to the herd and would leave no descendants. Those who return become the parents of the herd. As to the others the rough sea tells no tales. We know that, of those that set forth, a large percentage never comes back. To those that return the homing instinct has proved adequate. This must be so so long as the race exists. The failure of instinct would mean the extinction of the species.

130. Classification of instincts.—The instincts of animals may be roughly classified as to their relation to the individual into egoistic and altruistic instincts.

Egoistic instincts are those which concern chiefly the individual animal itself. To this class belong the instincts of feeding, those of self-defense and of strife, the instincts

of play, the climatic instincts, and environmental instincts, those which direct the animal's mode of life.

Altruistic instincts are those which relate to parenthood and those which are concerned with the mass of individuals of the same species. The latter may be called the social instincts. In the former class, the instincts of parenthood, may be included the instincts of courtship, reproduction, home-making, nest-building, and care for the young.

131. **Feeding.**—The instincts of feeding are primitively simple, growing complex through complex conditions. The protozoan absorbs smaller creatures which contain nutriment. The sea-anemone closes its tentacles over its prey. The barnacle waves its feelers to bring edible creatures within its mouth. The fish seizes its prey by direct motion. The higher vertebrates in general do the same, but the conditions of life modify this simple action to a very great degree.

In general, animals decide by reflex actions what is suitable food, and by the same processes they reject poisons or unsuitable substances. The dog rejects an apple, while the horse rejects a piece of meat. Either will turn away from an offered stone. Almost all animals reject poisons instantly. Those who fail in this regard in a state of nature die and leave no descendants. The wild vetches or "loco-weeds" of the arid regions affect the nerve centers of animals and cause dizziness or death. The native ponies reject these instinctively. This may be because all ponies which have not this reflex dislike have been destroyed. The imported horse has no such instinct and is poisoned. Very few animals will eat any poisonous object with which their instincts are familiar, unless it be concealed from smell and taste.

In some cases, very elaborate instincts arise in connection with feeding habits. With the California woodpeckers (*Melanerpes formicivorus bairdii*) a large number of them

together select a live-oak tree for their operations. They first bore its bark full of holes, each large enough to hold an acorn. Then into each hole an acorn is thrust (Figs. 61 and 62). Only one tree in several square miles may be selected, and when their work is finished all those interested go about their business elsewhere. At irregular intervals a dozen or so come back with much clamorous discussion to look at the tree. When the right time comes, they all return, open the acorns one by one, devouring apparently the substance of the nut, and probably also the grubs of beetles which have developed within. When the nuts are ripe, again they return to the same tree and the same process is repeated. In the tree figured this has been noticed each year since 1891.

132. **Self-defense.**—The instinct of self-defense is even more varied in its manifestations. It may show itself either in the impulse to make war on an intruder or in the desire to flee from its enemies. Among the flesh-eating mammals and birds fierceness of demeanor serves both for the securing of food and for protection against enemies. The stealthy movements of the lion, the skulking habits of the wolf, the sly selfishness of the fox, the blundering good-natured power of the bear, the greediness of the hyena, are all proverbial, and similar traits in the eagle, owl, hawk, and vulture are scarcely less matters of common observation.

Herbivorous animals, as a rule, make little direct resistance to their enemies, depending rather on swiftness of foot, or in some cases on simple insignificance. To the latter cause the abundance of mice and mouse-like rodents may be attributed, for all are the prey of carnivorous beasts and birds, and even snakes.

Even young animals of any species show great fear of their hereditary enemies. The nestlings in a nest of the American bittern when one week old showed no fear of man, but when two weeks old this fear was very manifest

(Figs. 153 and 154). Young mocking-birds will go into spasms at the sight of an owl or a cat, while they pay little attention to a dog or a hen. Monkeys that have never seen a snake show almost hysterical fear at first sight of one, and the same kind of feeling is common to most men. A monkey was allowed to open a paper bag which



FIG. 153.—Nestlings of the American bittern. Two of a brood of four birds one week old, at which age they showed no fear of man. Photograph by E. H. TABOR, Meridian, N. Y., May 31, 1898. (Permission of Macmillan Company, publishers of Bird-Lore.)

contained a live snake. He was staggered by the sight, but after a while went back and looked in again, to repeat the experience. Each wild animal has its special instinct of resistance or method of keeping off its enemies. The stamping of a sheep, the kicking of a horse, the running in a circle of a hare, and the skulking in a circle of some foxes, are examples of this sort of instinct.

133. Play.—The play instinct is developed in numerous animals. To this class belong the wrestlings and mimic fights of young dogs, bear cubs, seal pups, and young beasts generally. Cats and kittens play with mice. Squir-



FIG. 154.—Nestlings of the American bittern. The four members of the brood of which two are shown in Fig. 153, two weeks old, when they showed marked fear of man. Photograph by F. M. CHAPMAN, Meridian, N. Y., June 8, 1898. (Permission of Macmillan Company, publishers of Bird-Lore.)

rels play in the trees. Perhaps it is the play impulse which leads the shrike or butcher-bird to impale small birds and beetles on the thorns about its nest, a ghastly kind of ornament that seems to confer satisfaction on the bird itself. The talking of parrots and their imitations of the sounds they hear seem to be of the nature of play. The greater

their superfluous energy the more they will talk. Much of the singing of birds, and the crying, calling, and howling of other animals, are mere play, although singing primarily belongs to the period of reproduction, and other calls and cries result from social instincts or from the instinct to care for the young.

134. **Climate.**—Climatic instincts are those which arise from the change of seasons. When the winter comes the fur-seal takes its long swim to the southward; the wild geese range themselves in wedge-shaped flocks and fly high and far, calling loudly as they go; the bobolinks straggle away one at a time, flying mostly in the night, and most of the smaller birds in cold countries move away toward the tropics. All these movements spring from the migratory instinct. Another climatic instinct leads the bear to hide in a cave or hollow tree, where he sleeps or hibernates till spring. In some cases the climatic instinct merges in the homing instinct and the instinct of reproduction. When the birds move north in the spring they sing, mate, and build their nests. The fur-seal goes home to rear its young. The bear exchanges its bed for its lair, and its first business after waking is to make ready to rear its young.

135. **Environment.**—Environmental instincts concern the creature's mode of life. Such are the burrowing instincts of certain rodents, the woodchucks, gophers, and the like. To enumerate the chief phases of such instincts would be difficult, for as all animals are related to their environment, this relation must show itself in characteristic instincts.

136. **Courtship.**—The instincts of courtship relate chiefly to the male, the female being more or less passive. Among many fishes the male struts before the female, spreading his fins, intensifying his pigmented colors through muscular tension, and in such fashion as he can makes himself the preferred of the female. In the little brooks in spring male minnows can be found with warts on the nose or head,

with crimson pigment on the fins, or blue pigment on the back, or jet-black pigment all over the head, or with varied combinations of all these. Their instinct is to display all these to the best advantage, even though the conspicuous hues lead to their own destruction. Against this contingency Nature provides a superfluity of males.

Among the birds the male in spring is in very many species provided with an ornamental plumage which he sheds when the breeding season is over. The scarlet, crimson, orange, blue, black, and lustrous colors of birds are commonly seen only on the males in the breeding season, the young males and all males in the fall having the plain brown gray or streaky colors of the female. Among the singing birds it is chiefly the male that sings, and his voice and the instinct to use it are commonly lost when the young are hatched in the nest.

Among polygamous mammals the male is usually much larger than the female, and his courtship is often a struggle with other males for the possession of the female. Among the deer the male, armed with great horns, fight to the death for the possession of the female or for the mastery of the herd. The fur-seal has on an average a family of about thirty-two females (Fig. 71), and for the control of his harem others are ready at all times to dispute the possession. But with monogamous animals like the true or hair seal or the fox, where a male mates with a single female, there is no such discrepancy in size and strength, and the warlike force of the male is spent on outside enemies, not on his own species.

137. Reproduction.—The movements of many migratory animals are mainly controlled by the impulse to reproduce. Some pelagic fishes, especially flying-fishes and fishes allied to the mackerel, swim long distances to a region favorable for a deposition of spawn. Some species are known only in the waters they make their breeding homes, the individuals being scattered through the wide seas at

other times. Many fresh-water fishes, as trout, suckers, etc., forsake the large streams in the spring, ascending the small brooks where they can rear their young in greater safety. Still others, known as anadromous fishes, feed and mature in the sea, but ascend the rivers as the impulse of reproduction grows strong. Among such species are the salmon, shad, alewife, sturgeon, and striped bass in American waters. The most noteworthy case of the anadromous instinct is found in the king salmon or quinnat of the Pacific coast. This great fish spawns in November. In the Columbia River it begins running in March and April, spending the whole summer in the ascent of the river without feeding. By autumn the individuals are greatly changed in appearance, discolored, worn, and distorted. On reaching the spawning beds, some of them a thousand miles from the sea, the female deposits her eggs in the gravel of some shallow brook. After they are fertilized both male and female drift tail foremost and helpless down the stream, none of them ever surviving to reach the sea. The same habits are found in other species of salmon of the Pacific, but in most cases the individuals of other species do not start so early or run so far. A few species of fishes, as the eel, reverse this order, feeding in the rivers and brackish creeks, dropping down to the sea to spawn.

The migration of birds has relation to reproduction as well as to changes of weather. As soon as they reach their summer homes, courtship, mating, nest-building, and the care of the young occupy the attention of every species.

138. **Care of the young.**—In the animal kingdom one of the great factors in development has been the care of the young. This feature is a prominent one in the specialization of birds and mammals. When the young are cared for the percentage of loss in the struggle for life is greatly reduced, the number of births necessary to the maintenance of the species is much less, and the opportunities for specialization in other relations of life are much greater.

In these regards, the nest-building and home-making animals have the advantage over those that have not these instincts. The animals that mate for life have the advantage over polygamous animals, and those whose social or mating habits give rise to a division of labor over those with instincts less highly specialized.

The interesting instincts and habits connected with nest or home building and the care of the young are discussed in the next chapter.

139. Variability of instincts.—When we study instincts of animals with care and in detail, we find that their regularity is much less than has been supposed. There is as much variation in regard to instinct among individuals as there is with regard to other characters of the species. Some power of choice is found in almost every operation of instinct. Even the most machine-like instinct shows some degree of adaptability to new conditions. On the other hand, in no animal does reason show entire freedom from automatism or reflex action. “The fundamental identity of instinct with intelligence,” says an able investigator, “is shown in their dependence upon the same structural mechanism (the brain and nerves) and in their responsive adaptability.”

140. Reason.—Reason or intellect, as distinguished from instinct, is the choice, more or less conscious, among responses to external impressions. Its basis, like that of instinct, is in reflex action. Its operations, often repeated, become similarly reflex by repetition, and are known as habit. A habit is a voluntary action repeated until it becomes reflex. It is essentially like instinct in all its manifestations. The only evident difference is in its origin. Instinct is inherited. Habit is the reaction produced within the individual by its own repeated actions. In the varied relations of life the pure reflex action becomes inadequate. The sensorium is offered a choice of responses. To choose one and to reject the others is the function of intel-

lect or reason. While its excessive development in man obscures its close relation to instinct, both shade off by degrees into reflex action. Indeed, no sharp line can be drawn between unconscious and subconscious choice of reaction and ordinary intellectual processes.

Most animals have little self-consciousness, and their reasoning powers at best are of a low order; but in kind, at least, the powers are not different from reason in man. A horse reaches over the fence to be company to another. This is instinct. When it lets down the bars with its teeth, that is reason. When a dog finds its way home at night by the sense of smell, this may be instinct; when he drags a stranger to his wounded master, that is reason. When a jack-rabbit leaps over the brush to escape a dog, or runs in a circle before a coyote, or when it lies flat in the grass as a round ball of gray indistinguishable from grass, this is instinct. But the same animal is capable of reason—that is, of a distinct choice among lines of action. Not long ago a rabbit came bounding across the university campus at Palo Alto. As it passed a corner it suddenly faced two hunting dogs running side by side toward it. It had the choice of turning back, its first instinct, but a dangerous one; of leaping over the dogs, or of lying flat on the ground. It chose none of these, and its choice was instantaneous. It ceased leaping, ran low, and went between the dogs just as they were in the act of seizing it, and the surprise of the dogs, as they stopped and tried to hurry around, was the same feeling that a man would have in like circumstances.

On the open plains of Merced County, California, the jack-rabbit is the prey of the bald eagle. Not long since a rabbit pursued by an eagle was seen to run among the cattle. Leaping from cow to cow, he used these animals as a shelter from the savage bird. When the pursuit was closer, the rabbit broke cover for a barbed wire fence. When the eagle swooped down on it, the rabbit moved a few inches to the right, and the eagle could not reach him

through the fence. When the eagle came down on the other side, he moved across to the first. And this was continued until the eagle gave up the chase. It is instinct that leads the eagle to swoop on the rabbit. It is instinct again for the rabbit to run away. But to run along the line of a barbed wire fence demands some degree of reason. If the need to repeat it arose often in the lifetime of a single rabbit it would become a habit.

The difference between intellect and instinct in lower animals may be illustrated by the conduct of certain monkeys brought into relation with new experiences. At one time we had two adult monkeys, "Bob" and "Jocko," belonging to the genus *Macacus*. Neither of these possessed the egg-eating instinct. At the same time we had a baby monkey, "Mono," of the genus *Cercopithecus*. Mono had never seen an egg, but his inherited impulses bore a direct relation to feeding on eggs, just as the heredity of *Macacus* taught the others how to crack nuts or to peel fruit.

To each of these monkeys we gave an egg, the first that any of them had ever seen. The baby monkey, Mono, being of an egg-eating race, devoured his egg by the operation of instinct or inherited habit. On being given the egg for the first time, he cracked it against his upper teeth, making a hole in it, and sucked out all the substance. Then holding the egg-shell up to the light and seeing that there was no longer anything in it, he threw it away. All this he did mechanically, automatically, and it was just as well done with the first egg he ever saw as with any other he ate. All eggs since offered him he has treated in the same way.

The monkey Bob took the egg for some kind of nut. He broke it against his upper teeth and tried to pull off the shell, when the inside ran out and fell on the ground. He looked at it for a moment in bewilderment, took both hands and scooped up the yolk and the sand with which it was mixed and swallowed the whole. Then he stuffed the

shell itself into his mouth. This act was not instinctive. It was the work of pure reason. Evidently his race was not familiar with the use of eggs and had acquired no instincts regarding them. He would do it better next time. Reason is an inefficient agent at first, a weak tool; but when it is trained it becomes an agent more valuable and more powerful than any instinct.

The monkey Jocko tried to eat the egg offered him in much the same way that Bob did, but, not liking the taste, he threw it away.

The confusion of highly perfected instinct with intellect is very common in popular discussions. Instinct grows weak and less accurate in its automatic obedience as the intellect becomes available in its place. Both intellect and instinct are outgrowths from the simple reflex response to external conditions. But instinct insures a single definite response to the corresponding stimulus. The intellect has a choice of responses. In its lower stages it is vacillating and ineffective; but as its development goes on it becomes alert and adequate to the varied conditions of life. It grows with the need for improvement. It will therefore become impossible for the complexity of life to outgrow the adequacy of man to adapt himself to its conditions.

Many animals currently believed to be of high intelligence are not so. The fur-seal, for example, finds its way back from the long swim of two or three thousand miles through a foggy and stormy sea, and is never too late or too early in arrival. The female fur-seal goes two hundred miles to her feeding grounds in summer, leaving the pup on the shore. After a week or two she returns to find him within a few rods of the rocks where she had left him. Both mother and young know each other by call and by odor, and neither is ever mistaken, though ten thousand other pups and other mothers occupy the same rookery. But this is not intelligence. It is simply instinct, because it has no element of choice in it. Whatever its ancestors

were forced to do the fur-seal does to perfection. Its instincts are perfect as clockwork, and the necessities of migration must keep them so. But if brought into new conditions it is dazed and stupid. It can not choose when different lines of action are presented.

The Bering Sea Commission once made an experiment on the possibility of separating the young male fur-seals, or "killables," from the old ones in the same band. The method was to drive them through a wooden chute or runway with two valve-like doors at the end. These animals can be driven like sheep, but to sort them in the way proposed proved impossible. The most experienced males would beat their noses against a closed door, if they had seen a seal before them pass through it. That this door had been shut and another opened beside it passed their comprehension. They could not choose the new direction. In like manner a male fur-seal will watch the killing and skinning of his mates with perfect composure. He will sniff at their blood with languid curiosity; so long as it is not his own it does not matter. That his own blood may flow out on the ground in a minute or two he can not foresee.

Reason arises from the necessity for a choice among actions. It may arise as a clash among instincts which forces on the animal the necessity of choosing. A doe, for example, in a rich pasture has the instinct to feed. It hears the hounds and has the instinct to flee. Its fawn may be with her and it is her instinct to remain and protect it. This may be done in one of several ways. In proportion as the mother chooses wisely will be the fawn's chance of survival. Thus under difficult conditions, reason or choice among actions rises to the aid of the lower animals as well as man.

141. **Mind.**—The word mind is popularly used in two different senses. In the biological sense the mind is the collective name for the functions of the sensorium in men and animals. It is the sum total of all psychic changes,

actions and reactions. Under the head of psychic functions are included all operations of the nervous system as well as all functions of like nature which may exist in organisms without specialized nerve fibers or nerve cells. As thus defined mind would include all phenomena of irritability, and even plants have the rudiments of it. The operations of the mind in this sense need not be conscious. With the lower animals almost all of them are automatic and unconscious. With man most of them must be so. All functions of the sensorium, irritability, reflex action, instinct, reason, volition, are alike in essential nature though differing greatly in their degree of specialization.

In another sense the term mind is applied only to conscious reasoning or conscious volition. In this sense it is mainly an attribute of man, the lower animals showing it in but slight degree. The discussion as to whether lower animals have minds turns on the definition of mind, and our answer to it depends on the definition we adopt.



FIG. 155.—A "pointer" dog in the act of "pointing," a specialized instinct.
(Permission of G. O. Shields, publisher of Recreation.)

CHAPTER XV

HOMES AND DOMESTIC HABITS

142. Importance of care of the young.—The nest-building and domestic habits of animals are adaptations, but adaptations of behavior or habit rather than of structure, and are based on instinct, intelligence, and reason. These instincts and habits are among the most important shown by animals, because on them depends largely the continuance of the species. Of primary importance in the perpetuation of the species is the possession by animals of adaptations of structure and behavior, which help the individual live long enough to attain full development and to leave offspring. But in the case of many animals a successful start in life on the part of the offspring depends on the existence in the parents of certain domestic habits concerned with the care and protection of their young. The young of many animals depend absolutely, for a part of their lifetime, on this parental care. In these cases it is quite as necessary for the continued existence of the species that the habits that afford this care be successful as that the parent should come successfully to mature development and to the production of offspring.

143. Care of the young, and communal life.—The nest-building or home-making habits and the continued personal care of the young for a part of their lifetime are most highly developed and widespread among the birds, mammals, and insects; and it is both among the insects and the higher vertebrates that we find most developed those social and communal habits discussed in Chapter IX. The principal activities of an animal community have to do

with the protection and sustenance of the young, and the care of the young is undoubtedly a chief factor in the development of communal life.

144. **The invertebrates (except spiders and insects).—**Among the lower invertebrates parental aid to the young is confined almost exclusively to exhibitions of pure instinct. And this is true of many of the higher animals also. Eggs are deposited in sheltered places, and in such places and under such circumstances that the young on hatching will find themselves close to a supply of their natural food. The depositing of eggs in water by parents with terrestrial habits whose young are aquatic, is an example. The toad, which lives on land, feeding on insects, has young which live in water and feed on minute aquatic plants (algæ). The dragon fly, that hawks over the pond or brook with glistening wings, has young that crawl in the slime and mud at the bottom of the pool. With most animals, after laying eggs, the parents show no further solicitude toward their offspring. The eggs are left to the vicissitudes of fortune, and the parents know nothing of their fate. In many cases the parent dies before the young are hatched. The mammals and birds are the only two great groups excepted, although there are numerous specific exceptions scattered among the lower invertebrates, fishes, batrachians, and higher invertebrates, notably the insects.

There are no instances of care of the young after hatching among the sponges, polyps, worms, or star-fishes and sea-urchins, and but few among the crustaceans and mollusks. But there are in some of these groups a few cases of nest or home building in a crude and simple way. Certain sea-urchins (Fig. 156) and worms and mollusks bore into stones, and remain in the shelter afforded by the cavity. A shell-fish (*Lima hians*) cements together bits of coralline, shells, and sand to form a crude nest or hiding-place. The cray-fish digs a cylindrical burrow in the ground in which it can hide.

145. Spiders.—Most spiders spin silken cocoons or sacs in which to deposit their eggs. Some spiders carry this egg-filled cocoon about with them for the sake of protecting the eggs. After hatching, the spiderlings remain in the cocoon a short time, feeding on each other! Thus only the

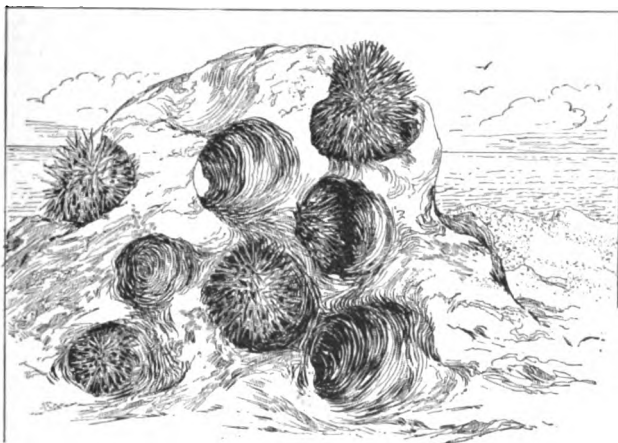


FIG. 156.—Sea-urchins living in holes bored into rocks of the seashore below high-tide line.

strongest survive and issue from the cocoon to earn their living in the outer world. With certain species of spiders the young after hatching leave the cocoon and gather on the back of the mother and are carried about by her for some time. In connection with their webs or snares many spiders have silken tunnels or tubes in which to lie hidden, a sort of sheltering nest. Those spiders that live on the ground make for themselves cylindrical burrows or holes in the ground, usually lined with silk, in which they hide when not hunting for food. Especially interesting among the many kinds of these spider nests are the burrows of the various trap-door spiders. These spiders are common in California and some other far Western States. The bur-

row (Fig. 157) or cylindrical hole is closed above by a silken, thick, hinged lid or door, a little larger in diameter than the hole and neatly beveled on the edge, so as to fit tightly into and perfectly cover the hole when closed. The upper surface of the door is covered with soil, bits of leaves, and wood, so as to resemble very exactly the ground surface about it. We have found these trap-door nests in California in moss-covered ground, and here the lids of the nests were always covered with green, growing moss.

An English naturalist who studied the habits of these trap-door spiders found that if he removed the soil and bits of bark and twigs, or the moss, from the upper surface of the lid the spider always re-covered it. It is, of course, plain that by means of this covering the nest is perfectly concealed, the surface of the closed door not being different from the surrounding ground surface. This naturalist finally removed the moss not only from the surface of a trap-door, but also from all the ground in a circle of a few feet about the nest. The next day he found that the spider had brought moss from outside the cleared space and covered the trap-door with it, thus making it very conspicuous in the cleared ground space. The spider's instinct was not capable of that quick modification to allow it to do what a reasoning animal would have done—namely, covered the trap-door only with soil to make it resemble the cleared ground about it.

Another interesting nest-making spider is the turret-spider, that builds up a little tower (Fig. 158) of sticks and soil and moss above its burrow. The sticks of which this burrow are built are an inch or two in length, and are arranged in such manner as make the turret five-sided. The sticks are fastened together with silk, and the turret is made two or three inches high. This turret-building spider is one of those that carry about their egg-cocoon with them. A female of this spider in captivity was observed to pay much attention to caring for this cocoon.

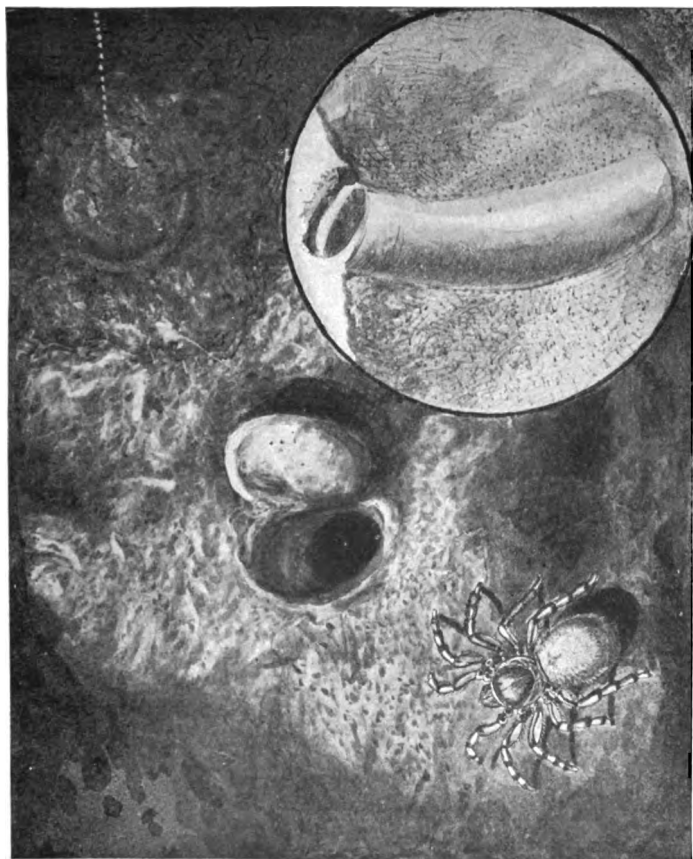


FIG. 157.—Trap-door spider (*Cteniza californica*) and nest. In lower right-hand corner of figure, diagram of nest; in upper right-hand corner, a closed trap-door; and in center, an open trap-door.

"If the weather was cold or damp, she retired to her tunnel; but if the jar in which she lived was set where the sun could shine upon it, she soon re-appeared and allowed the cocoon to bask in the sunlight. If the jar was placed near a stove that had a fire in it, the cocoon was put on the side next the source

of warmth; if the jar was turned around, she lost no time in moving the cocoon to the warmer side. Two months after the eggs were laid the young spiders made their

appearance and immediately perched upon their mother, many on her back, some on her head, and even on her legs. She carried them about with her and fed them, and until they were older they never left their mother for a moment."

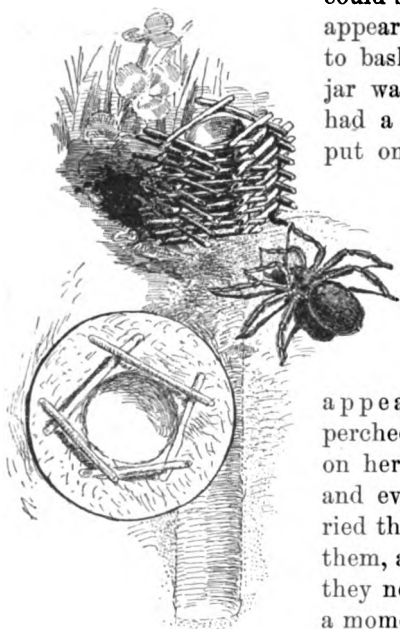


FIG. 158.—Nest of the turret-spider.

146. **Insects.**—So much space has already been devoted to an

account of the elaborate nest-making and domestic habits of the bees, ants, and termites (see Chapter IX), that we need in this place merely refer to that account. It is among these social insects that the most interesting and highly specialized habits connected with the care of the young and the building of homes are found.

Many insects make for themselves simple burrows or nests in the ground or in wood. The young or larvæ of certain moths burrow about in the soft inside tissue of leaves, and the whole life of the moth except its short adult stage is passed inside the leaf. These larvæ are called leaf-

miners. The larvæ of some moths and of many hymenopterous insects live in galls on live plants. These galls are simply abnormal growths of plant tissue, and are caused by the irritating effect on the tissue of the larvæ which hatch from eggs that have been thrust into the soft plant substance by the female insects. In the familiar galls on the golden-rod live the larvæ of a small moth, and in the various kinds of oak galls live the young of the numerous species of *Cynipidæ*, the hymenopterous gall insects. The tiny larvæ of some of the midges live in small galls on various plants. To this last group of gall-making insects belongs the dreaded Hessian fly, the most destructive insect pest of wheat.

Among the bees and wasps only a few species, comparatively, are communal or live in communities. But nearly all the wasps and bees, whether social or solitary in habit, build nests for their young and provide the young with food, either by storing it in the nest or by hunting for it and bringing it to the nest as long as the young are in the larval condition. The "mud-daubers" or thread-waisted wasps make nests of mud attached to the lower surface of flat stones, to the ceiling of buildings, or in other out-of-the-way and safe places. These nests usually have the form of several tubes an inch or so long placed side by side. In each of the tubes or cells an egg is laid, and with it a spider which has been stung so as to be paralyzed but not killed. When the young wasp hatches from the egg as a grub or larva, it feeds on the unfortunate spider. Others of the solitary wasps make nests in the ground or in wood, and all of them provision their nests with some particular kind of insect or spider. Some use only caterpillars, some plant-lice, and some grasshoppers. Similarly the solitary bees make nests in the ground as do the mining-bees, or in wood as do the carpenter-bees, or by cutting and fastening together leaves, as do the leaf-cutting bees. The bees provision their nests, not with paralyzed

insects, but with masses of pollen or pollen mixed with nectar.

147. The vertebrates.—It is among the vertebrates, especially in the higher groups, the birds and mammals, that we find the care of the young most perfectly undertaken and most widespread.

Among the fishes, the lowest of the vertebrates, most species content themselves with the laying of many eggs in a situation best suited for their safe hatching. But some species show interesting domestic habits. The female catfish swims about with her brood, much as a hen moves about with her chickens. Some of the larger ocean catfish of the tropics receive the eggs or the young within the mouth for safety in time of danger. Certain sunfishes care for their young, keeping them together in still places in the brook. They also make some traces of a nest, which the male defends. The male salmon scoops out gravel to make a shallow nest, in which the female deposits her eggs. The male then covers the eggs. The males of the species of pipe-fish and sea-horses receive the eggs of the female into a groove or sac between the folds of skin on the lower part of the tail. Here they are kept until the little fishes are large enough to swim about for themselves. The brave little sticklebacks build tiny nests about an inch and a half or two inches in diameter, with a small opening at the top. The eggs are laid in this nest, and the young fish remain in it some time after hatching. The male parent jealously guards the nest, and fights bravely with would-be intruders.

The batrachians and reptiles rarely show any care for their young. The eggs of most batrachians are laid in the water and left by the female. The males of the Surinam toad receive the eggs in pits of the spongy skin of the back, where they remain until the young hatch. The eggs of snakes are laid under logs or buried in the sand, and no further attention is given them by the parents.

Among the birds, on the other hand, nest-building and

care of the young are the rule, and a high degree of development in these habits is reached. All of us are familiar with many different kinds of nests, from the few twigs loosely put together by the mourning-dove to the firm, closely knit, wool or feather lined nest of the humming-bird (Fig. 159), and the basket-like hanging nest of the



FIG. 159.—Nest and eggs of the Rufus humming-bird (*Trochilus rufus*). Photograph by J. O. SNYDER, Stanford University, California.

oriole (Fig. 161). Not all birds make nests. On the rocky islets of the northern oceans, where thousands of puffins and auks and other maritime birds gather to breed, the eggs are laid on the bare rock. At the other extreme is the tailor bird of India, which sews together leaves by means of fibrous strips plucked from a growing plant to



FIG. 160.—Nest and young of the Rufus humming-bird (*Trochilus rufus*). Photograph by J. O. SNYDER, Stanford University, California.



FIG. 161.—Baltimore orioles and nest; the male in upper left-hand corner of figure.

form a long, bag-like nest (Fig. 162). In the degree of care given the nestlings there is also much difference. The robin brings food to the helpless young for many days, and

finally teaches it to fly and to hunt for food for itself. Young chickens are not so helpless as the nestling robins, but are able to run about, and under the guiding care of the hen mother to pick up food for themselves.



FIG. 162.—Tailor-bird (*Ornithotomus sutorius*) and nest.

Among the mammals the young are always given some degree of care. Excepting in the case of the duck-bills, the lowest of the mammals, the young are born alive—that is, are not hatched from eggs laid outside the body—and are nourished after birth for a shorter or longer time with milk drawn from the body of the mother. Before birth the young undergoes a longer or shorter

period of development and growth in the body of the mother, being nourished by the blood of the mother. The nests or homes of mammals present varying degrees of elaborateness, from a simple cave-like hole in the rocks or ground to the elaborately constructed villages of the beavers with their dams and conical several-storied houses (Fig. 163). The wood-rat piles together sticks and twigs in what seems, from the outside, a most haphazard fashion, but which results in the construction of a convenient and ingenious nest. The moles and pocket-gophers (Fig. 165) build underground nests composed of chambers and gal-

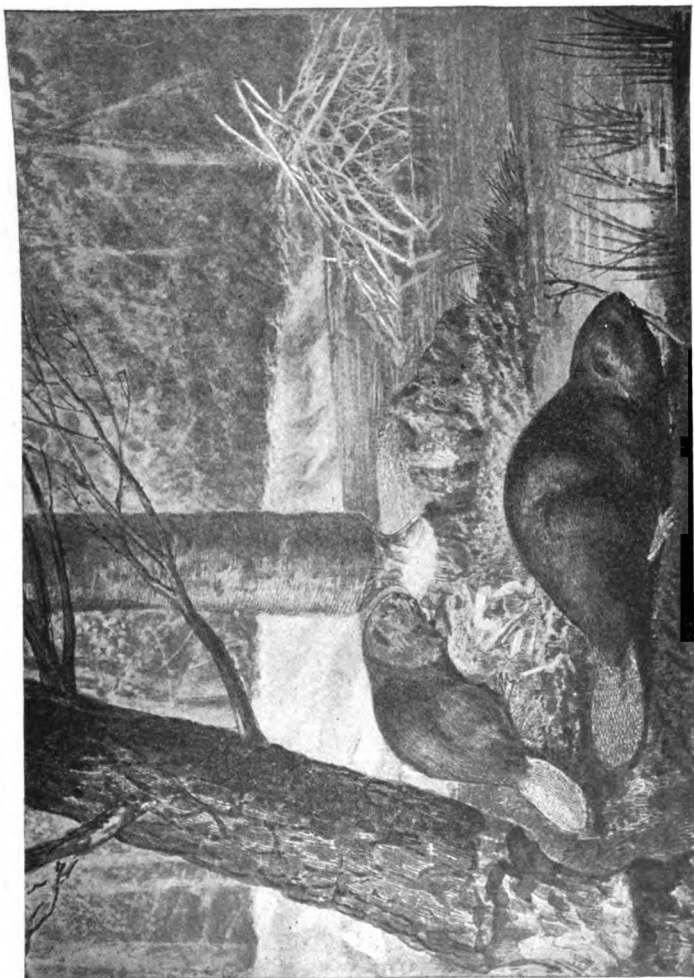


FIG. 103.—Beavers making a nest.

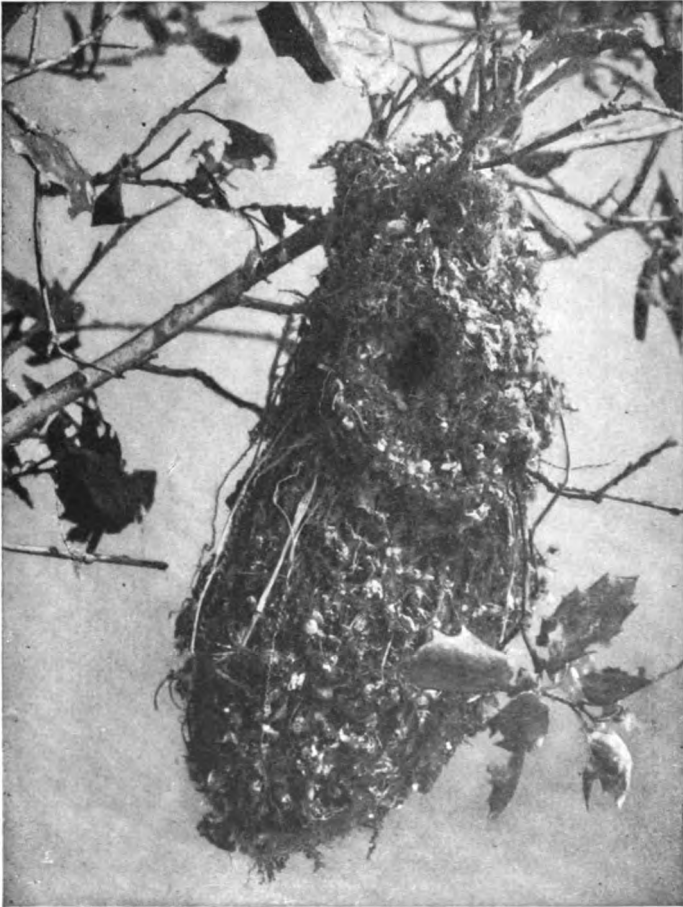


FIG. 164.—Nest of the Californian bush-tit (*Psaltiriparus minimus*). Photograph by G. O. SNYDER, Stanford University, California.

leries. The prairie-dogs make burrows in groups, forming large villages.

The devotion to their young displayed by birds and mammals is familiar to us. The parents will often risk or

suffer the loss of their own lives in protecting their offspring from enemies. Many mother birds have the instinct to flutter about a discovered nest crying and apparently broken-winged, thus leading the predatory fox or weasel to

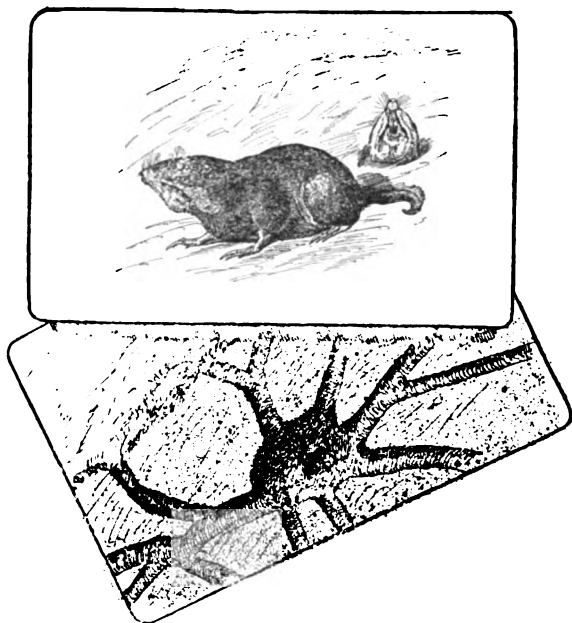


FIG. 165.—Nest and run-way of the pocket-gopher.

fix his attention on the mother and to leave the nest unharmed. This development of parental care and protection of the young reaches its highest degree in the case of the human species. The existence of the family, which is the unit of human society, rests on this high development of care for the young.

CHAPTER XVI

GEOGRAPHICAL DISTRIBUTION OF ANIMALS

148. **Geographical distribution.**—Under the head of distribution we consider the facts of the diffusion of organisms over the surface of the earth, and the laws by which this diffusion is governed.

The geographical distribution of animals is often known as *zoögeography*. In physical geography we may prepare maps of the earth which shall bring into prominence the physical features of its surface. Such maps would show here a sea, here a plateau, here a range of mountains, there a desert, a prairie, a peninsula, or an island. In political geography the maps show the physical features of the earth, as related to the states or powers which claim the allegiance of the people. In zoögeography the realms of the earth are considered in relation to the types or species of animals which inhabit them. Thus a series of maps of the United States could be drawn which would show the gradual disappearance of the buffalo before the attacks of man. Another might be drawn which would show the present or past distribution of the polar bear, black bear, and grizzly. Still another might show the original range of the wild hares or rabbits of the United States, the white rabbit of the Northeast, the cotton-tail of the East and South, the jack-rabbit of the plains, the snowshoe rabbit of the Columbia River, the tall jack-rabbit of California, the black rabbits of the islands of Lower California, and the marsh-hare of the South and the water-hare of the canebrakes, and that of all their relatives. Such a

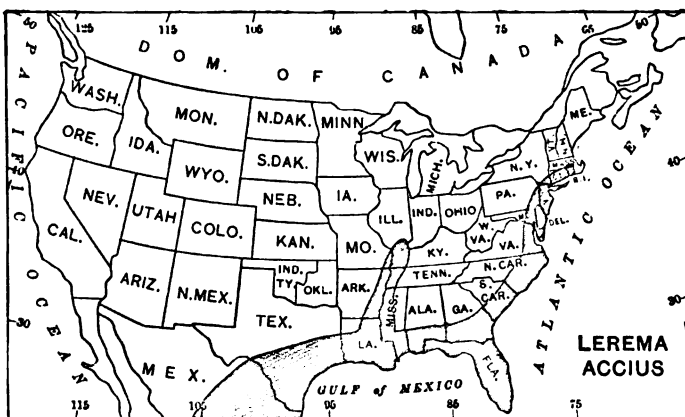


FIG. 166.—Map showing the distribution of the clouded Skipper butterfly (*Lerema accius*) in the United States. The butterfly is found in that part of the country shaded in the map, a warm and moist region.—After SCUDDER.

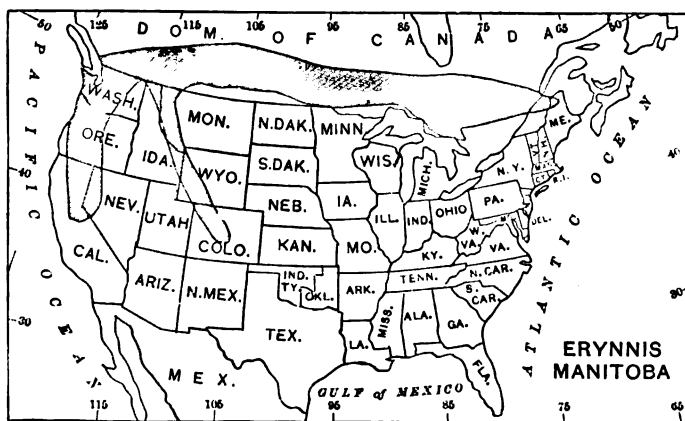


FIG. 167.—Map showing the distribution of the Canadian Skipper butterfly (*Erynnis manitoba*) in the United States. The butterfly is found in that part of the country shaded in the map. This butterfly is subarctic and subalpine in distribution, being found only far north or on high mountains, the two southern projecting parts of its range being in the Rocky Mountains and in the Sierra Nevada Mountains.—After SCUDDER.

map is very instructive, and it at once raises a series of questions as to the reasons for each of the facts in geographical distribution, for it is the duty of science to suppose that none of these facts is arbitrary or meaningless. Each fact has some good cause behind it.

149. Laws of distribution.—The laws governing the distribution of animals are reducible to three very simple propositions. Every species of animal is found in every part of the earth having conditions suitable for its maintenance, unless—

(a) Its individuals have been unable to reach this region, through barriers of some sort; or—

(b) Having reached it, the species is unable to maintain itself, through lack of capacity for adaptation, through severity of competition with other forms, or through destructive conditions of environment; or—

(c) Having entered and maintained itself, it has become so altered in the process of adaptation as to become a species distinct from the original type.

150. Species debarred by barriers.—As examples of the first class we may take the absence of kingbirds or meadow-larks or coyotes in Europe, the absence of the lion and tiger in South America, the absence of the civet-cat in New York, and that of the bobolink or the Chinese flying-fox in California. In each of these cases there is no evident reason why the species in question should not maintain itself if once introduced. The fact that it does not exist is, in general, an evidence that it has never passed the barriers which separate the region in question from its original home.

Local illustrations of the same kind may be found in most mountainous regions. In the Yosemite Valley in California, for example, the trout ascend the Merced River to the base of a vertical fall. They can not rise above this, and so the streams and lakes above this fall are destitute of fish.

151. Species debarred by inability to maintain their ground.—Examples of the second class are seen in animals which man has introduced from one country to another. The nightingale, the starling, and the skylark of Europe have been repeatedly set free in the United States. But none of these colonies has long endured, perhaps from lack of adaptation to the climate, more likely from severity of competition with other birds. In other cases the introduced species has been better fitted for the conditions of life than the native forms themselves, and so has gradually crowded out the latter. Both these cases are illustrated among the rats. The black rat, first introduced into America from Europe about 1544, helped crowd out the native rats, while the brown rat, brought in still later, about 1775, in turn practically exterminated the black rat, its fitness for the conditions of life here being still greater than that of the other European species.

Certain animals have followed man from land to land, having been introduced by him against his will and to the detriment of his domestic animals or crops. To many of these the term vermin has been applied. Among the vermin or "animal weeds" are certain of the rodents (rats, mice, rabbits, etc.), the mongoose of India, the English sparrow, and many kinds of noxious insects. Of all the vermin of this class few have caused such widespread destruction of property as the common European rabbit introduced into Australia. The annual loss through its presence is estimated at \$3,500,000.

It often happens that man himself so changes the environment of a species that it can no longer maintain itself. Checking the increase of a species, either by actually killing off its members or by adverse change in its surroundings, is to begin the process of its destruction. Circumstances become unfavorable to the growth or reproduction of an animal. Its numbers are reduced, fewer are born each year, and fewer reach maturity, it grows rare,

is gone, and the final step of extinction may often pass unnoticed.

But a few years ago the air in the Ohio Valley was dark in the season of migration with the hordes of passenger pigeons. The advance of a tree-destroying, pigeon-shooting civilization has gone steadily on, and now the bird which once crowded our Western forests is in the same region an ornithological curiosity. The extinction of the American bison or "buffalo," and the growing rarity of the grizzly bear, the wolf, and of large carnivora generally, furnishes cases in point. When Bering and Steller landed on the Commander Islands in 1741, the sea-cow, a large herbivorous creature of the shores, was abundant there. In about fifty years the species, being used for food by fishermen, entirely disappeared. In most cases, however, a species that crosses its limiting barriers, but is unable to maintain itself, leaves no record of the occurrence. We know, as a matter of fact, that stray individuals are very often found outside the usual limit of a species. A tropical bird may be found in New Jersey, a tropical fish on Cape Cod, or a bird from Europe on the shores of Maine. Of course, hundreds of other cases of this sort must escape notice; but, for one reason or another, the great majority of these waifs are unable to gain a new foothold. For this reason, outside of the disturbances created by man, the geographical distribution of species changes but little from century to century; and yet, when we study the facts more closely, evidences of change appear everywhere.

152. **Species altered by adaptation to new conditions.**—Of the third class or species altered in a new environment examples are numerous, but in most cases the causes involved can only be inferred from their effects. One class of illustrations may be taken from island faunæ. An island is set off from the mainland by barriers which species of land animals can very rarely cross. On an island a few waifs of wave and storm may maintain themselves, increasing in



FIG. 168.—The manatee, or sea-cow (*Trichechus latirostris*). A living species of sea-cow related to the now extinct Steller's sea-cow.

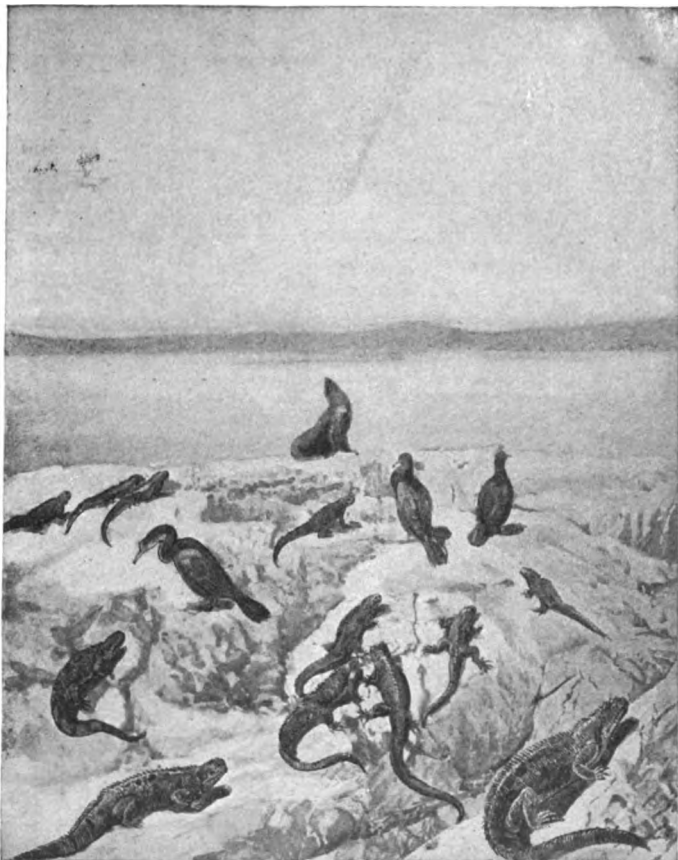


FIG. 169.—On the shore of Narborough Island, one of the Galapagos Islands, Pacific Ocean, showing peculiar species of sea-lions, lizards, and cormorants. Drawn from a photograph made by Messrs. SNODGRASS and HELLER.

numbers so as to occupy the territory; but in so doing only those will survive that can fit themselves to the new conditions. Through this process a new species will be formed, like the parent species in general structure, but having gained new traits adjusted to the new environment.

The Galapagos Islands are a cluster of volcanic rocks lying in the open sea about six hundred miles to the west of Ecuador. On these islands is a peculiar land fauna, derived from South American stock, but mostly different in species. Darwin noted there "twenty-six land birds; of these, twenty-one, or perhaps twenty-three, are ranked as distinct species. Yet the close affinity of most of these birds to American species is manifest in every character, in their habits, gestures, and tones of voice."

Among land animals similar migrations may occur, giving rise, through the adaptation to new conditions, to new species. The separation of species of animals isolated in river basins or lakes often permits the acquisition of new characters, which is the formation of distinct species in similar fashion. On the west side of Mount Whitney, the highest mountain in the Sierra Nevada of California, there is a little stream called Volcano Creek. In this brook is a distinct species or form of trout, locally called golden trout. It is unusually small, very brilliantly colored, its fins being bright golden, and its tiny scales scarcely overlap each other along its sides. This stream flows over a high waterfall (Agua Bonita) into the Kern River. The Kern River is full of trout, of a kind (*Salmo gilberti*) to which the golden trout is most closely allied. There can not be much doubt that the latter is descended from the former. With this assumption, it is easy to suppose that once the waterfall did not exist, or that through some agency we can not now identify certain fishes had been carried over it. Once above it, they can not now return, nor can they mix with the common stock of the river. Those best adapted to the little stream have survived. The process of adaptation has gone on till at last a distinct species (or sub-species*) is formed. In recent times the

* In descriptive works the name species is applied to a form when the process of adaptation seems complete. When it is incomplete, or

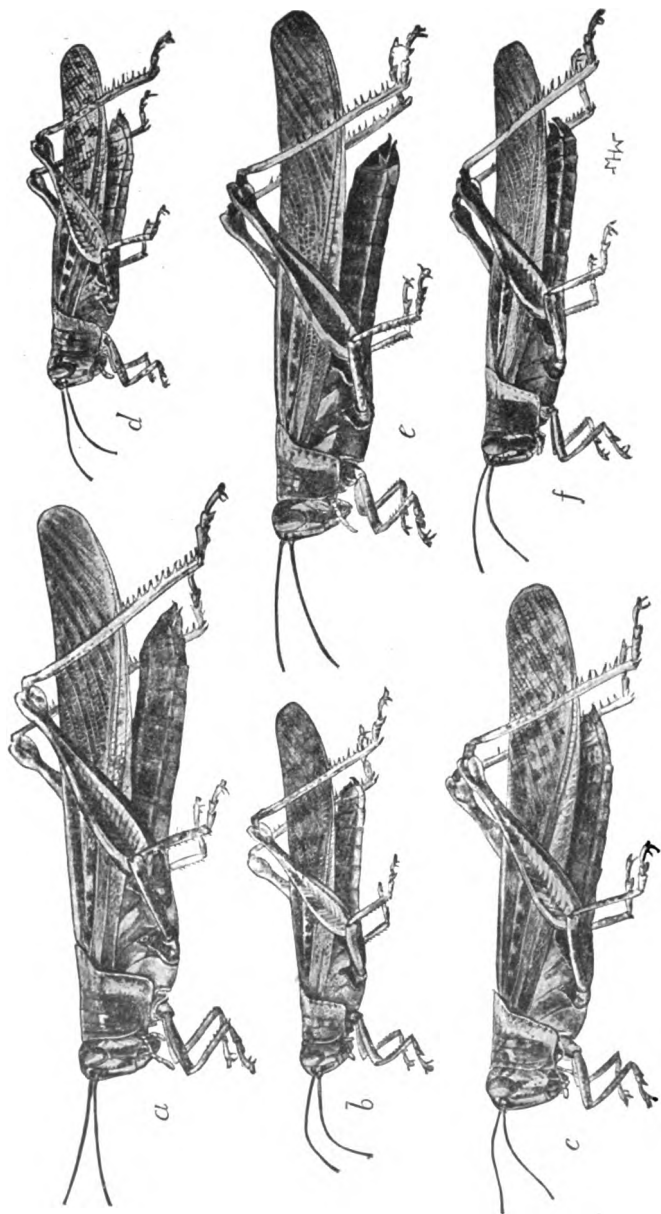


FIG. 170.—Locusts (*Schistocerca*) taken on the Galapagos Islands, Pacific Ocean; all descended from a common ancestor, but now scattered over the various islands, and varying in size and markings. *a*, *Schistocerca melanocera* Stol (Charles Island); *b*, *S. intermedia borealis* Snodgrass (Abingdon and Bindloe Islands); *c*, *S. intermedia* Snodgrass (Duncan Island); *d*, *S. heteroa* Walker (Chatham Island); *e*, *S. melanocera lineata* Snodgrass (Albemarle Island); *f*, *S. melanocera immaculata* Snodgrass (Indefatigable Island). (The species *intermedia* is probably a hybrid between the other two species.)

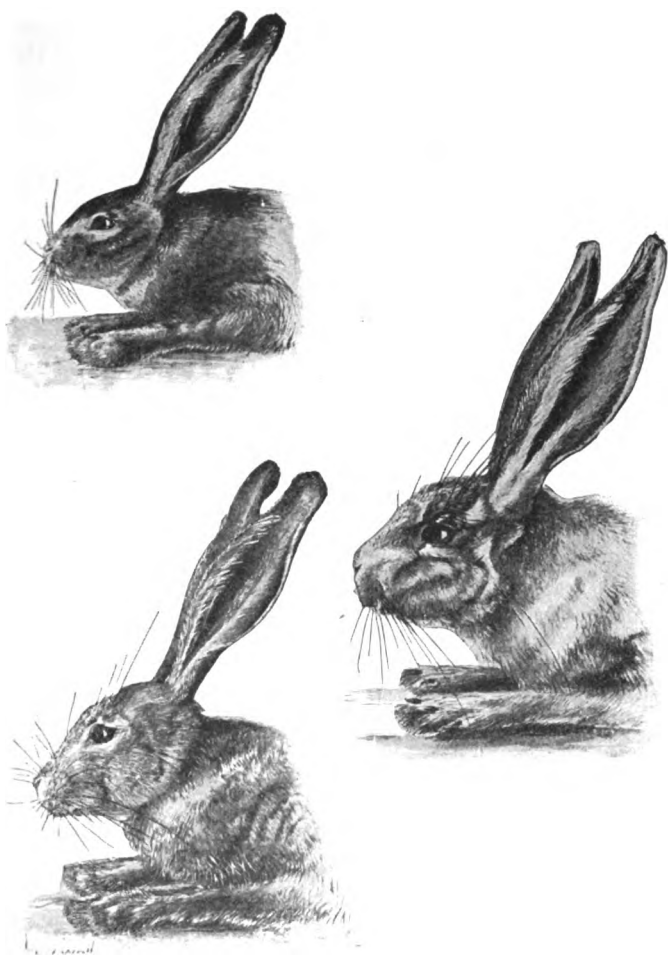


FIG. 171.—Three species of jack-rabbits, differing in size, color, and markings, but believed to be derived from a common stock. The differences have arisen through isolation and adaptation. The upper figure shows the head and fore legs of the black jack-rabbit (*Lepus insularis*), of Espiritu Santo Island, Gulf of California; the lower right-hand figure, the Arizona jack-rabbit (*Lepus allenti*), specimen from Fort Lowell, Arizona; and the lower left-hand figure is the San Pedro Martir jack-rabbit (*Lepus martirensis*), from San Pedro Martir, Baja California.

hand of man has carried the golden trout to other little mountain torrents, where it thrives as well as in the one where its peculiarities were first acquired.

Other cases of this nature are found among the blind fishes of the caves in different parts of the world (Fig. 172).

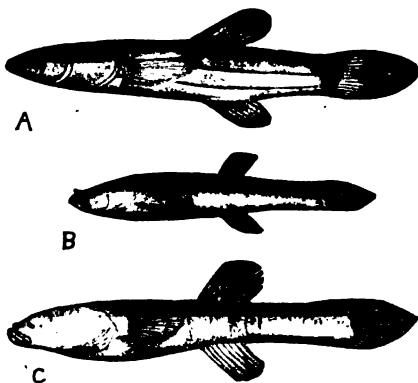


FIG. 172.—Fishes showing stages in the loss of eyes and color. A, Dismal Swamp fish (*Chologaster avitus*), ancestor of the blind fish; B, Agassiz's cave fish (*Chologaster agassizi*); C, cave blind fish (*Typhlichthys subterraneus*).

In general, caves are formed by the erosion or wearing of underground rivers. These streams are usually clear and cold, and when they issue to the surface those fishes that like cold and shaded waters are likely to enter them. But to have eyes in absolute darkness, in which no use can be made of them, is a disadvantage in the struggle for life.

Hence the eyed species die or withdraw, while those in which the eye grows less from generation to generation, until its function is finally lost, are the ones which survive. By such processes the blind fishes in the limestone caves of Kentucky, Indiana, Tennessee, and Missouri have been formed.

rather when specimens showing intergradation of characters are known, the word *sub-species* is used. The word variety has much the same meaning when used for a subdivision of a species, but it is a term defined with less exactness. Thus the common fox (*Vulpes pennsylvanicus*) is a distinct species, being separate from the arctic fox or the gray fox or the fox of Europe. The cross fox (*Vulpes pennsylvanicus decussatus*) is called a sub-species, as is the silver fox (*Vulpes pennsylvanicus argentatus*), because these intergrade perfectly with the common red fox.

To processes of this kind, on a larger or smaller scale, the variety in the animal life of the globe is very largely due. Isolation and adaptation give the clew to the formation of a very large proportion of the "new species" in any group. /

153. Effect of barriers.—It will be thus seen that geographical distribution is primarily dependent on barriers or checks to the movement of animals. The obstacles met in the spread of animals determine the limits of the species. Each species broadens its range as far as it can. It attempts unwittingly, through natural processes of increase, to overcome the obstacles of ocean or river, of mountain or plain, of woodland or prairie or desert, of cold or heat, of lack of food or abundance of enemies—whatever the barriers may be. Were it not for these barriers, each type or species would become cosmopolitan or universal. Man is pre-eminently a barrier-crossing animal. Hence he is found in all regions where human life is possible. The different races of men, however, find checks and barriers entirely similar in nature to those experienced by the lower animals, and the race peculiarities are wholly similar to characters acquired by new species under adaptation to changed conditions. The degree of hindrance offered by any barrier differs with the nature of the species trying to surmount it. That which constitutes an impassable obstacle to one form may be a great aid to another. The river which blocks the monkey or the cat is the highway of the fish or the turtle. The waterfall which limits the ascent of the fish is the chosen home of the ouzel. The mountain barrier which the bobolink or the prairie-dog does not cross may be the center of distribution of the chief hare or the arctic blue-bird.

154. Relation of species to habitat.—The habitat of a species of animal is the region in which it is found in a state of Nature. It is currently believed that the habitat of any creature is the region for which it is best adapted.

But the reverse of this is often true. There are many cases in which a species introduced in a new territory, through the voluntary or involuntary influence of man, has shown a marvelous adaptation and power of persistence. The rapid spread of rabbits and pigs as wild animals in Australia, of horses and cattle in South America, and of the English sparrow in North America, of bumble-bees and house-flies in New Zealand, are illustrations of this. Not one of these animals has maintained itself in the wild state in its native land as successfully as in these new countries to which it has been introduced. The work of introduction of useful animals illustrates the same fact. The shad, striped bass, and cat-fish from the Potomac River, introduced into the Sacramento River and its tributaries by the United States Fish Commission, are examples in point. These valued food-fishes are nowhere more at home than in the new waters where no species of their types had ever existed before. The carp, originally brought to Europe from China, and thence to the United States as a food-fish, becomes in California a nuisance, which can not be eradicated, destroying the eggs and the foodstuff of far better fish.

In all mountain regions waterfalls are likely to occur, and these serve as barriers, preventing the ascent of trout and other fishes. On this account in the mountains of California, Colorado, Wyoming, and other States, hundreds of lakes and streams suitable for trout are found in which no fishes ever exist. In the Yellowstone Park this fact is especially noticeable. This region is a high volcanic plateau, formed by the filling of an ancient granite basin with a vast deposit of lava. The streams of the park are very cold and clear, in every way favorable for the growth of trout; yet, with the exception of a single stream, the Yellowstone River, none of the streams was found to contain any fish in that part of it lying on the plateau. Below the plateau all of them are well stocked. The reason for this is ap-

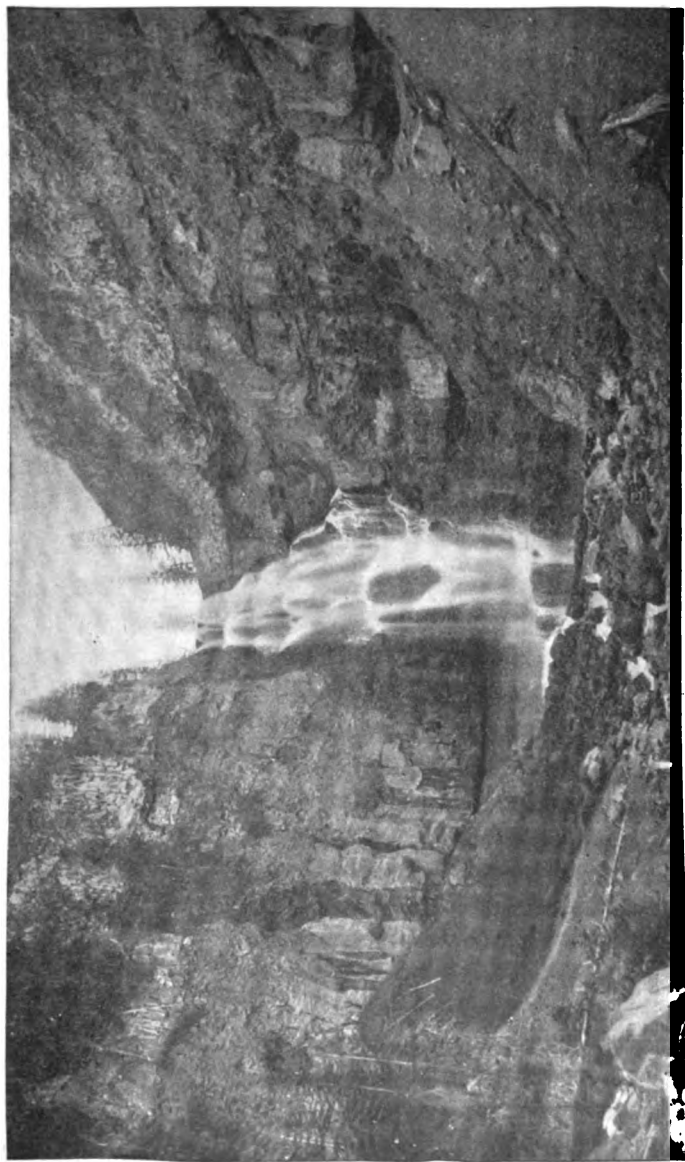
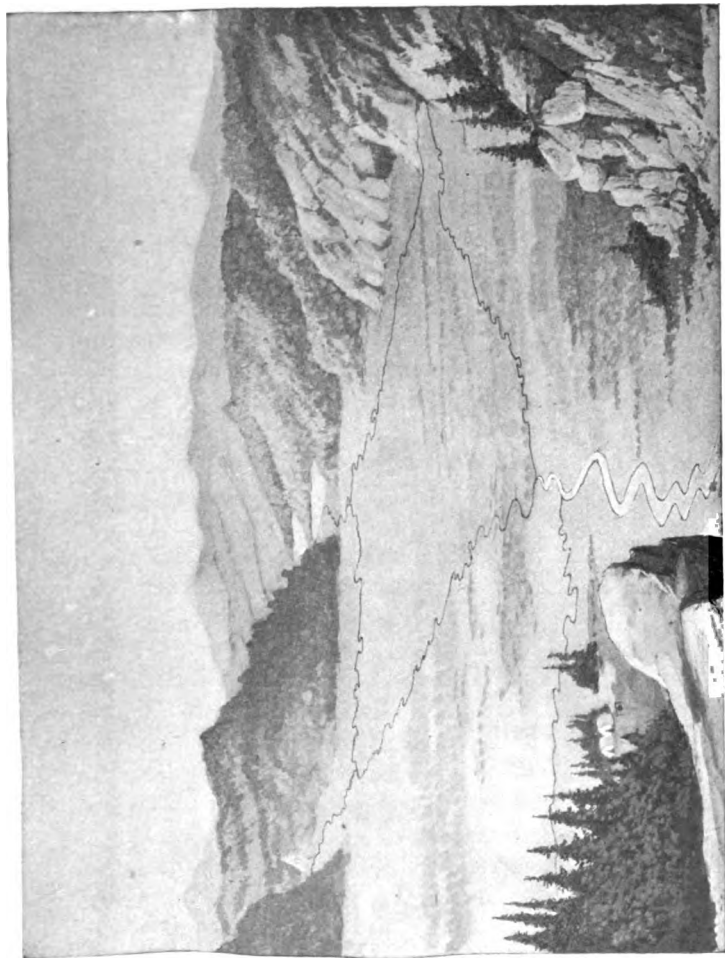


FIG. 173.—Osprey Falls, on Gardiner River, Yellowstone Park. These falls prevent the ascent of trout, which are common in the river below the falls, to that part of the river (on the plateau) above the falls.

parent in the fact that the plateau is fringed with cataracts which fishes can not ascend. Each stream has a cañon or deep gorge with a waterfall at its head, near the point where it leaves the hard bed of black lava for the rock below (Fig. 173). So for an area of fifteen hundred square miles within the Yellowstone National Park the streams were without trout because their natural inhabitants had never been able to reach them. When this state of things was discovered it was easy to apply the remedy. Trout of different species were carried above the cascades, and these have multiplied with great rapidity.

The exception noted above, that of the Yellowstone River itself, evidently needs explanation. An abundance of trout is found in this river both above and below the great falls, and no other fish occurs with it. This anomaly of distribution is readily explained by a study of the tributaries at the head waters of the river. When we ascend above Yellowstone Lake to the continental divide, we find on its very summit that only about an eighth of a mile of wet meadow and marsh, known as Two Ocean Pass (Fig. 174), separates the drainage of the Yellowstone from that of the Columbia. A stream known as Atlantic Creek flows into the Yellowstone, while the waters of Pacific Creek on the other side find their way into the Snake River. These two creeks are connected by waterways in the wet meadow, and trout may pass from one to the other without check. Thus from the Snake River the Yellowstone received its trout, and from the Yellowstone they have spread to the streams tributary to the upper Missouri.

This case is a type of the anomalies in distribution of which the student of zoögeography will find many. But each effect depends upon some cause, and a thorough study of the surroundings or history of a species will show what this cause may be. In numerous cases in which fishes have been found above an insurmountable cascade, the cause is seen in a marsh flooded at high water, connecting one



← Pacific Creek

FIG. 174.—Two Ocean Pass, summit of the continental divide between the Yellowstone and Snake Rivers, Atlantic Creek flowing eastward into Yellowstone River. Pacific Creek flowing southwestward into Snake River, the two creeks connected in the wet meadow by cross streams.

drainage basin with another. An example of this is found in Lava Creek in Yellowstone Park. Above Undine and Wraith Falls, both insurmountable, are found an abundance of trout. A marsh dry in summer connects Lava Creek with Black Tail Deer Creek, a tributary of the Yellowstone and without waterfall. From the Yellowstone through this creek and marsh the trout find their way into Lava Creek. In California numerous anomalies have been noted, as the occurrence of Tahoe trout in Feather River and in the Blue Lakes of Amador, which are on the other side of the main crest of the Sierra Nevada from Lake Tahoe, and the occurrence of the Whitney golden trout in Lone Pine Creek, another similar instance. In each case naturalists have found the man who actually carried the species across the divide. If this matter had been investigated a generation later, these cases would have been unexplainable anomalies in geographical distribution. Real causes are almost always simple when they are once known.

The ways in which species may cross barriers in a state of Nature are as varied as the creatures themselves, and far more varied than the actual barriers. By the long-continued process of adjustment to conditions with the incessant destruction of the unadapted, the various organisms have become so well fitted to their surroundings that the casual observer may well suppose that each inhabits the region best fitted for it. Men have even thought that the conditions of life have been fitted to the creatures themselves, so perfect is this relation.

155. Character of barriers to distribution.—Taking the animal kingdom as a whole, the two great barriers modifying distribution are the presence of the sea and changes in temperature. It is only in rare cases that any land animals can cross either of the great oceans, and these rare cases relate chiefly to the arctic regions. For this reason the land faunæ of Africa, South America, and Australia

have developed almost independently of one another. To the fresh-water fishes the sea forms equally a barrier, and

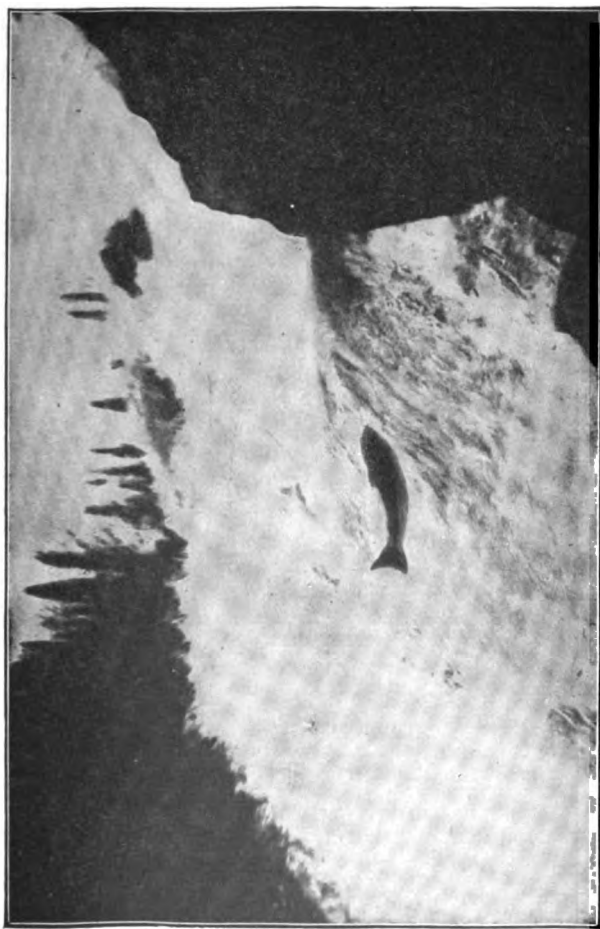


FIG. 173.—A Labrador salmon clearing an 18-foot waterfall. Photograph by Dr. R. T. Morris. (Permission of G. O. Shields, publisher of Recreation.)

even the shore-fishes very rarely pass across great depths. Relatively few of the shore-fishes of Cuba, for example, ever cross the deep Florida Straits, and none of those of Cali-

ifornia ever reach Honolulu, nor are Hawaiian shore-fishes ever seen on the coast of California. For these reasons natural boundaries of the great realms of distribution are found in the sea.

The other great check to distribution is found in heat and cold. Most of the tropical animals can not endure frost. The arctic animals, however fierce or active, are enfeebled by heat. The timber line, north of which and above which frost occurs the year round, therefore serves

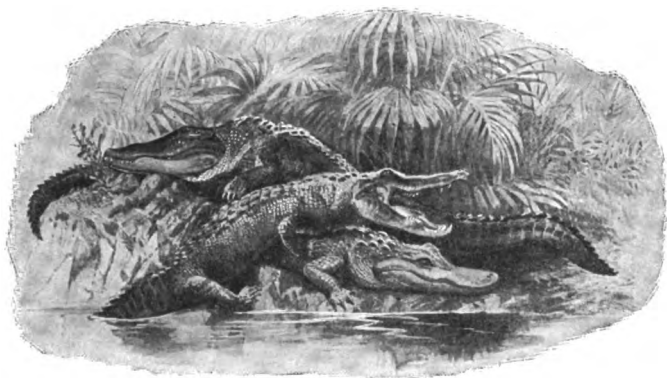


FIG. 176.—Alligators ; animals found only in the warm waters of tropical and sub-tropical regions.

as a boundary of limitation. Another equally marked is the frost line. Even the fishes of the tropics are extremely sensitive to slight cold. Off Florida Keys the cutlass-fish is sometimes seen stiff and benumbed on the water, where the temperature is scarcely below 60° Fahr. A "norther" on the Gulf of Mexico will sometimes bring fishes which live in considerable depths to the surface, through chilling the water. These barriers are rarely crossed by localized species, but many forms, especially birds, keep within a relatively uniform temperature through migration. The summers are spent in the north or in the mountains, the winters in districts that are warmer.

The climate, as distinct from the temperature, also greatly influences many species. In the Eastern United States and in the extreme Northwest, as in Europe and much of Asia, the atmosphere is humid all the year long. Rains occur at intervals in the summer, and rain or snow in the winter. The green season is from spring to fall, and the resting of plants is in the winter. To this condition the native animals adapt themselves, and this would seem to be the natural order of things.

But as we pass the Western plains of Nebraska, Kansas, and Texas this condition is materially changed. For part of the year rainfall is practically unknown. The air becomes dry, and under the cloudless sky the greater part of the vegetation ripens its seed and perishes. This is the arid climate. When the rainfall is very scant the region is never covered with verdure, and is known as desert. Such great desert tracts are found in parts of Wyoming, Utah, Nevada, Idaho, Colorado, Arizona, New Mexico, California, as well as in the northern parts of Mexico. In some cases the deserts are exposed to great heat, forming an ultra-torrid region, as in Death Valley in California and in certain parts of Arizona.

But the arid region is not as a whole desolate. In many parts rain falls more or less heavily for part of the year, bringing a rank growth of annual grasses and of verdure in general. In California this rainfall is in the winter, the coldest part of the year, and the country is green from November or October to June or May. In Mexico and northward to Colorado the chief rainfall is in midsummer, the warmest part of the year, and the summer is the time of verdure.

To all these conditions the plant life must adapt itself and with this the animal life. But the species that have become fitted to the arid habitat have undergone some change in the process and may have become different species. It is, then, not easy for them to recross the barrier

of climate to compete with those forms already adapted. For this reason a marked change of climate like a marked change of temperature forms a natural barrier to distribution and serves to circumscribe a natural fauna.

Closely associated with climate is the nature of forest growth, the growth of grass, and in general the development of conditions which serve for food or shelter to animals. These conditions depend in part on soil, partly on climate and topography, and partly on the acts of man. The forest and forest soils, acting like a great sponge, retain the waters of the rainy season, and thus regulate the size of the streams. The stream that changes least in volume is most favorable to the life of fishes, frogs, and water animals generally. The destruction of forests on the mountain sides acts adversely to the life of these creatures as well as to the interests of the farmer below whose lands the streams should water. When the forests are destroyed, the great host of wood creatures, the bears, squirrels, warblers, various birds, beasts, and insects of the woods can no longer maintain themselves, and grow rare and disappear. For reasons that are obvious the conditions that produce forest, prairie, canebrake, sage-desert, cactus-desert, and the like are potent in regulating the distribution of the species.

Still another set of conditions depends on the food supply. The planting of orchards tends to multiply greatly the number of individuals of those species which prey upon fruit. When food is abundant the severity of the struggle for life is relaxed and individuals increase in number. A species may be put to great stress by the disappearance of the animal or plant on which it has depended. Each change made by man among the wild animals or plants may have far-reaching effects upon others. The coyote or prairie-wolf destroys sheep in the ranges of the West. It is thinned out by means of the bounty upon its scalp. Then the jack-rabbit, on which it also feeds, greatly in-

creases in abundance, injuring fruit trees and grain fields. It is then necessary to pay for its destruction also.

To destroy hawks or owls because they catch chickens may increase the numbers and destructiveness of field-mice on which they also prey. To shoot robins, linnets, and other birds that destroy small fruits is likely to increase greatly the insect pests on which these birds also feed. The inter-relations of species and species are so close that none should be exterminated by man unless its habits and relations have been subjected to careful scientific study. Still less should any new ones be introduced without the fullest consideration of the possible results. For example, the mongoose, a weasel-like creature, was introduced from India into Jamaica to kill rats and mice. It killed also the lizards, and thus produced a plague of fleas, an insect which the lizards kept in check. The English sparrow, introduced that it might feed on insects inhabiting shade-trees, has become a nuisance, crowding out better birds and not accomplishing the purpose for which it was brought to the United States.

To most kinds of animals a mountain range must act as a barrier to distribution. In a region having high mountains a species will become in time split up into several, because the individuals in one valley will be isolated from those of another. The fauna of California furnishes many illustrations of this, as among its mountain chains are many deep valleys shut off from each other and having different peculiarities of temperature. For this reason two counties of California differ much more widely in their fauna than do two counties in Illinois. But Illinois as a whole has more different kinds of animals than California, because no barrier anywhere prevents their entrance. The State has, we may say, its doors wide open to immigrants from all quarters. The same is true of Iowa or of Kansas or Kentucky. Illinois has a richer fauna than Iowa, because its extension is north and south, and it therefore

covers a wider range of climate. Kentucky has a richer fauna than Iowa because it includes a greater variety of conditions. New England was called by Professor Agassiz a "zoölogical island," because of the relatively small number of its native animals, especially of species inhabiting its rivers. The cause of this is found in its isolation, being shut off from the Middle States by mountain ranges, while it is bounded on two sides by the sea.

156. Barriers affecting fresh-water animals.—The animals inhabiting fresh-water streams are affected by differences in temperature and elevation much as land animals are. They tend to spread from stream to stream whenever they can find their way. An isolated stream is likely to have its peculiar fauna just as island life is likely to differ from that of the mainland. The same species wanders widely within the limits of a single river basin. If a kind of fish establishes itself anywhere in the Mississippi Valley, it may find its way to every stream in the whole basin. If it likes cold spring water, as the rainbow-darter does, we may look for it in any cold spring. If, like the long-eared sun-fish, it frequents deep pools in the brooks, we may look for it under roots of stumps and in every "swimming hole." If, like the channel-cat, it chooses the ripples of a river, we may fish for it wherever ripples are. The larger the whole river basin the more species find their way into it, and therefore the greater the number of species in any one of its streams.

Each species finds its habitat fitted to its life, and then in turn is forced to adapt itself to this habitat. Any other kind of habitat then appears as a barrier to its distribution. Thus to a fish of the ripples a stretch of still water becomes a barrier. A species adapted to sandy bottoms will seldom force its way through swift waters or among weeds or rocks. The effect of waterfalls as barriers is elsewhere noticed. In some streams the dam made by a colony of beavers has the same effect. Mill-dams and artificial

waterfalls have checked the movements of many species, while others have been helped by artificial channels or canals. Streams that run muddy at times are not favorable for animal life. Still less favorable is the condition frequent in the arid region in which streams are full to the banks in the rainy season and shrunk to detached pools in the dry months.

The stream that has the greatest variety of animals in it would be one (1) connected with a large river, (2) in a warm climate, (3) with clear water and (4) little fluctuation from winter to summer, (5) with little change in the clearness of the water, (6) a gravelly bottom, (7) preferably of limestone, and (8) covered in its quiet reaches and its ripples with water-weeds. These conditions are best realized in tributaries of the Ohio, Cumberland, Tennessee, and Ozark Rivers among American streams, and it is in them that the greatest number of species of fresh-water animals (fishes, cray-fishes, mussels, etc.) has been recorded. These streams approach most nearly to the ideal homes for animals of the fresh waters. The streams of Wisconsin, Michigan, and the Columbia region have many advantages, but are too cold. Those of Illinois, Iowa, northern Missouri, and Kansas are too sluggish, and sometimes run muddy. Those of Texas and California shrink too much in summer, and are too isolated. The streams of the Atlantic coast are less isolated, but none connect with a great basin, and those of New England run too cold for the great mass of the species. For similar reasons the fresh-water animal life of Europe is relatively scanty, that of the Danube and Volga being richest. The animal life of the fresh water of South America centers in the Amazon, and that of Africa in the Nile, the Niger, and the Congo. The great rivers of Siberia, like the Yukon in Alaska and the Mackenzie River in British America, have but few forms of fresh-water animals, though those kinds fitted for life in cold, clear water exist in great abundance.

157. **Modes of distribution.**—The means and modes of migration and distribution are obvious in the case of animals that can fly or swim or make long journeys on foot. An island can be visited and become peopled by birds from the nearest mainland. Fishes and marine mammals can travel from ocean to ocean. But many animals have no means of crossing watery barriers. "Oceanic islands, that have been formed *de novo* in mid-ocean and are not detached portions of pre-existing continents, are almost invariably free from such animals as are incapable of traversing the sea. If sufficiently distant from any continent, oceanic islands are generally without mammals, reptiles, and amphibia, but have both birds and insects and certain other invertebrates which are transported to them by involuntary migration."

As suggested in the last sentence, migration may be passive or involuntary. For example, those minute animals that can become dried up and yet retain the power of renewing their active life under favorable conditions are sometimes carried in the dried mud adhering to the feet of birds, and may thus become widely distributed. Parasites are carried by their hosts in all their wanderings. Some animals, as rats and mice, are carried by ships and railway trains and thus widely distributed.

158. **Fauna and faunal areas.**—The term fauna is applied to the animals of any region considered collectively. Thus the fauna of Illinois comprises the entire list of animals found naturally in that State. It includes the aboriginal men, the black bear, the fox, and all its animal life down to the *Amæba*. The relation of the fauna of one region to that of another depends on the ease with which barriers may be crossed. Thus the fauna of Illinois differs little from that of Indiana or Iowa, because the State contains no barriers that animals may not readily pass. On the other hand, the fauna of California or Colorado differs materially from that of adjoining regions, because a moun-

tainous country is full of barriers which obstruct the diffusion of life. Distinctness is in direct proportion to isolation. What is true in this regard of the fauna of any region is likewise true of its individual species. The degree of resemblance among individuals is in strict proportion to the freedom of their movements. Variation within the limits of a species is again proportionate to the barriers which prevent equal and free diffusion.

159. Realms of animal life.—The various divisions or *realms* into which the land surface of the earth may be divided on the basis of the character of animal life have their boundary in the obstacles offered to the spread of the average animal. In spite of great inequalities in this regard, we may yet roughly divide the land of the globe into seven principal realms or areas of distribution, each limited by barriers, of which the chief are the presence of the sea and the occurrence of frost. There are the Arctic, North Temperate, South American, Indo-African, Lemurian, Patagonian, and Australian realms. Of these the Australian realm alone is sharply defined. Most of the others are surrounded by a broad fringe of debatable ground that forms a transition to some other zone.

The *Arctic realm* includes all the land area north of the isotherm of 32°. Its southern boundary corresponds closely with the northern limit of trees. The fauna of this region is very homogeneous. It is not rich in species, most of the common types of life of warmer regions being excluded. Among the large animals are the polar bear, the walrus, and certain species of "ice-riding" seals. There are a few species of fishes, mostly trout and sculpins, and a few insects. Some of these, as the mosquito, are excessively numerous in individuals. Reptiles are absent from this region and many of its birds migrate southward in the winter, finding in the arctic only their breeding homes. When we consider the distribution of insects and other small animals of wide diffusion we must add to the arctic realm all high moun-

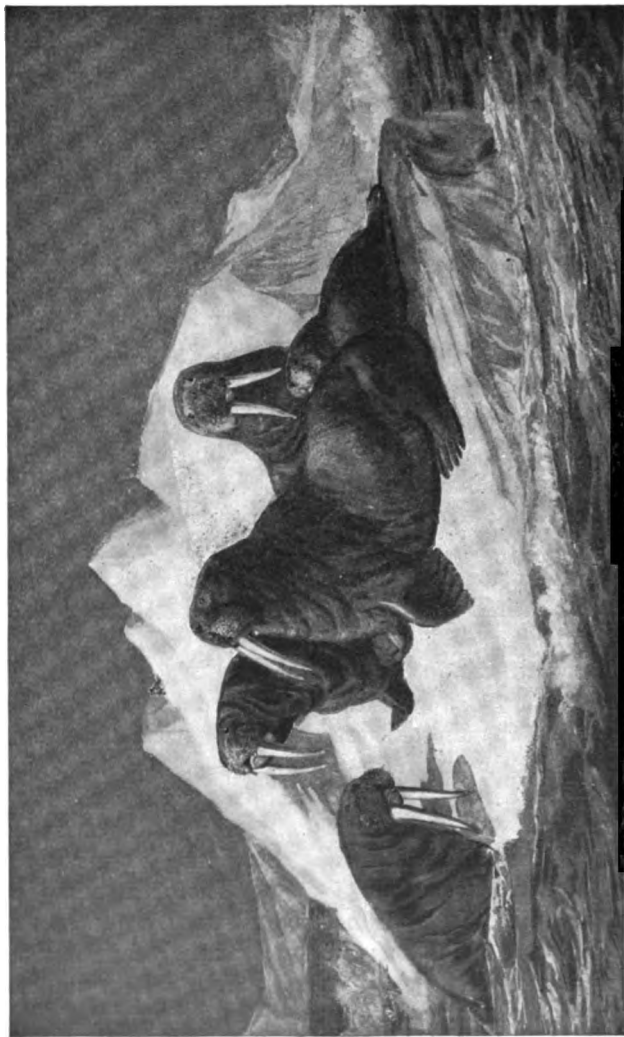


Fig. 177.—The Atlantic walrus (*Odobenus rosmarus*) ; animals of the arctic realm.

tains of other realms whose summits rise above the timber line. The characteristic large animals of the arctic, as the polar bear or the musk-ox or the reindeer, are not found there, because barriers shut them off. But the flora of the mountain top, even under the equator, may be characteristically arctic, and with the flowers of the north may be found the northern insects on whose presence the flower depends for its fertilization. So far as climate is concerned high altitude is equivalent to high latitude. On certain mountains the different zones of altitude and the corresponding zones of plant and insect life are very sharply defined (Fig. 178).

The *North Temperate realm* comprises all the land between the northern limit of trees and the southern limit of frost. It includes, therefore, nearly the whole of Europe, most of Asia, and most of North America. While there are large differences between the fauna of North America and that of Europe and Asia, these differences are of minor importance and are scarcely greater in any case than the difference between the fauna of California and that of our Atlantic coast. The close union of Alaska with Siberia gives the arctic region an almost continuous land area from Greenland to the westward around to Norway. To the south everywhere in the temperate zone realm the species increase in number and variety, and the differences between the fauna of North America and that of Europe are due in part to the northward extension into the one and the other of types originating in the tropics. Especially is this true of certain of the dominant types of singing birds. The group of wood-warblers, tanagers, American orioles, vireos, mocking-birds, with the fly-catchers and humming-birds so characteristic of our forests, are unrepresented in Europe. All of them are apparently immigrants from the neotropical realm where nearly all of them spend the winter. In the same way central Asia has many immigrants from the Indian realm to the southward. With all these variations there

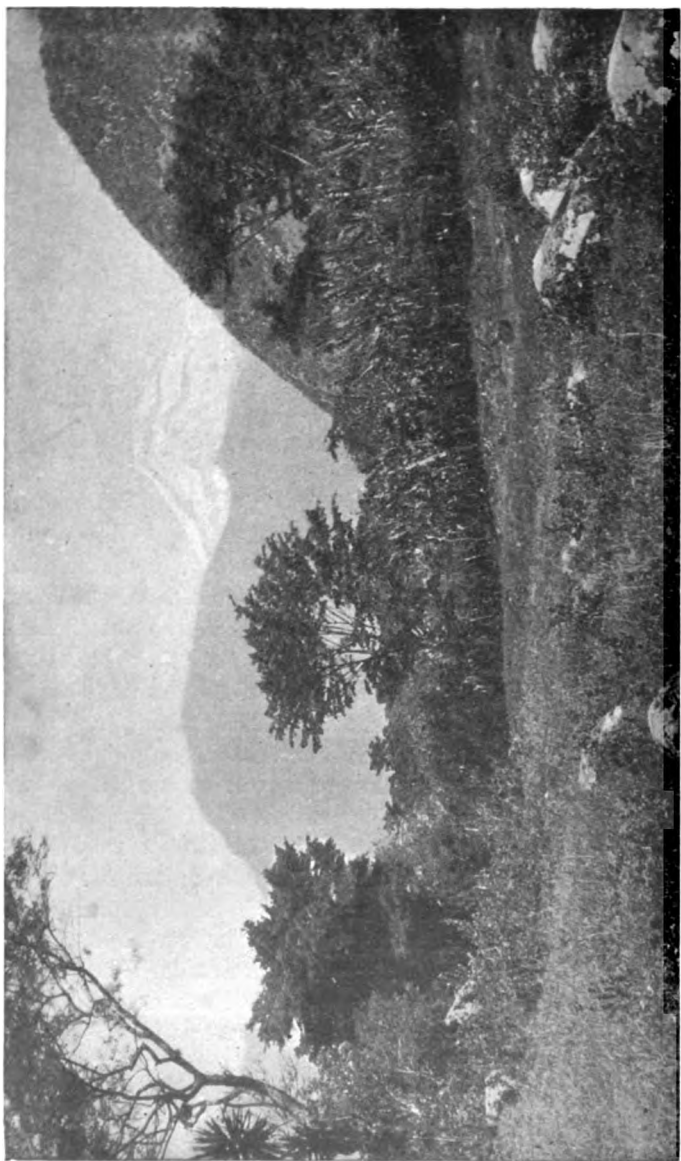


FIG. 178.—Mt. Orizaba, a high mountain rising near the city of Orizaba, Mexico, and showing zones of climate and life from tropical (at base) to arctic (at summit).

is an essential unity of life over this vast area, and the recognition of North America as a separate (nearctic) realm, which some writers have attempted, seems hardly practicable.

The *Neotropical* or *South American realm* includes South America, the West Indies, the hot coast lands of Mexico, and those parts of Florida and Texas where frost does not occur. Its boundaries through Mexico are not sharply defined, and there is much overlapping of the north temperate realm along its northern limit. Its birds especially range widely through the United States in the summer migrations, and a large part of them find in the North their breeding home. Southward, the broad barrier of the two oceans keeps the South American fauna very distinct from that of Africa or Australia. The neotropical fauna is richest of all in species. The great forests of the Amazon are the dreams of the naturalists. Characteristic types among the larger animals are the snout or broad-nosed (platyrrhine) monkeys, which in many ways are very distinct from the monkeys and apes of the Old World. In many of them the tip of the tail is highly specialized and is used as a hand. The Edentates (armadillos, ant-eaters, etc.) are characteristically South American, and there are many peculiar types of birds, reptiles, fishes, and insects.

The *Indo-African realm* corresponds to the neotropical realm in position. It includes the greater part of Africa, merging gradually northward into the north temperate realm through the transition districts which border the Mediterranean. It includes also Arabia, India, and the neighboring islands, all that part of Asia south of the limit of frost. In monkeys, carnivora, ungulates, and reptiles this region is wonderfully rich. In variety of birds, fishes, and insects the neotropical realm exceeds it. The monkeys of this district are all of the narrow-nosed (catarrhine) type, various forms being much more nearly related to man than is the case with the peculiar monkeys of South

America. Some of these (anthropoid apes) have much in common with man, and a primitive man derived from these has been imagined by Haeckel and others. No creature of this character is yet known, but that it may have once existed is not impossible. To this region belong the elephant, the rhinoceros, and the hippopotamus, as well as the lion, tiger, leopard, giraffe, the wild asses, and horses of various species, besides a large number of ruminant animals not found in other parts of the world. It is, in fact, in its lower mammals and reptiles that its



FIG. 179.—A lemur (*Lemur variegatus*).

most striking distinctive characters are found. In its fish fauna it has very much in common with South America.

The *Lemurian realm* comprises Madagascar alone. It is an isolated division of the Indo-African realm, but the presence of many species of lemur and an unspecialized or primitive type of lemur is held to justify its recognition as a distinct

realm. In most other groups of animals the fauna of Madagascar is essentially that of neighboring parts of Africa.

The *Patagonian realm* includes the south temperate zone of South America. It has much in common with the neotropical realm from which its fauna is mainly derived,

but the presence of frost is a barrier which vast numbers of species can not cross. Beyond the Patagonian realm lies the Antarctic continent. The scanty fauna of this region is little known, and it probably differs from the Patagonian fauna chiefly in the absence of all but the ice-riding species.

The *Australian realm* comprises Australia and the neighboring islands. It is more isolated than any of the others, having been protected by the sea from the invasions of the characteristic animals of the Indo-African and temperate realms. It shows a singular persistence of low or primitive types of vertebrate life, as though in the process of evolution the region had been left a whole geological age behind the others. It is certain that if the closely competing fauna of Africa and India could have been able to invade Australia, the dominant mammals and birds of that region would not have been left as they are now—marsupials and parrots.

It is only when barriers have shut out competition that simple or unspecialized types abound. The larger the land area and the more varied its surface, the greater is the stress of competition and the more specialized are its characteristic forms. As part of this specialization is in the direction of hardiness and power to persist, the species from the large areas, as a whole, are least easy of extermination. The rapid multiplication of rabbits and foxes in Australia, when introduced by the hand of man, shows what might have taken place in this country had not impassable barriers of ocean shut them out.

160. **Subordinate realms or provinces.**—Each of these great realms may be indefinitely subdivided into provinces and sections, for there is no end to the possibility of analysis. No school district has exactly the same animals or plants as any other, as finally in ultimate analysis we find that no two animals or plants are exactly alike. Shut off one pair of animals from the others of its species, and its descendants will differ from the parent stock. This differ-

ence increases with time and with distance so long as the separation is maintained. Hence new species and new fauna or aggregations of species are produced wherever free diffusion is checked by any kind of barrier.

161. **Faunal areas of the sea.**—In like manner, we may divide the oceans into faunal areas or zones, according to the distribution of its animals. For this purpose the fishes probably furnish the best indications, although results very similar are obtained when we consider the mollusks or the crustacea. The fresh-water fishes are not considered here, as in regard to their faunal areas they agree with the land animals of the same regions. Perhaps the most important basis for primary divisions is found in the separation from the localized shore-fishes of the cosmopolitan pelagic species, and the scarcely less widely distributed bassalian species or fishes of the deep sea.

The *pelagic* fishes are those which inhabit the open sea, swimming near the surface, and often in great schools. Such forms are mainly confined to the warmer waters. They are for the most part predatory fishes, strong swimmers, and many of the species are found in all warm seas. Most species have special homing waters, to which they repair in the spawning season. Often there will be special regions to which they never resort, either for breeding or for food. At other times a certain species will appear in numbers in regions where it has hitherto been unknown. For example, the frigate-mackerel (*Auxis thazard*), homing in the East Indies and the Mediterranean, appeared in great numbers in 1880 off the coast of New England. Typical pelagic fishes are the mackerel, tunny, dolphin, flying-fish, opah, and some species of shark. This group shades off by degrees into the ordinary shore-fish, some being partly pelagic, venturing out for short distances, and some are pelagic for part of the year only. To the free-swimming forms of classes of animals lower than fishes, found in the open ocean, the name *Plankton* is applied.

The *bassalian* fauna, or deep-sea fauna, is composed of species inhabiting great depths (2,500 feet to 25,000 feet) in the sea. At a short distance below the surface the change in temperature from day to night is no longer felt. At a still lower depth there is no difference between winter and summer, and still lower none between day and night.

The bassalian fishes inhabit a region of great cold and inky darkness. Their bodies are subjected to great pressure, and the conditions of life are practically unvarying. There is therefore among them no migration, no seasonal change, no spawning season fixed by outside conditions, and no need of adaptation to varying environment. As a result, all are uniform indigo-black in color, and all show more or less degeneration in those characters associated with ordinary environment. Their bodies are elongate, from the lack of specialization in the vertebræ. The flesh, being held in place by the great

pressure of the water, is soft and fragile. The organs of touch are often highly developed. The eye is either excessively large, as if to catch the slightest ray of light, or else it is undeveloped, as if the fish had abandoned the effort to see. In many cases luminous spots or lanterns are developed by which the fish may see to guide his way in the

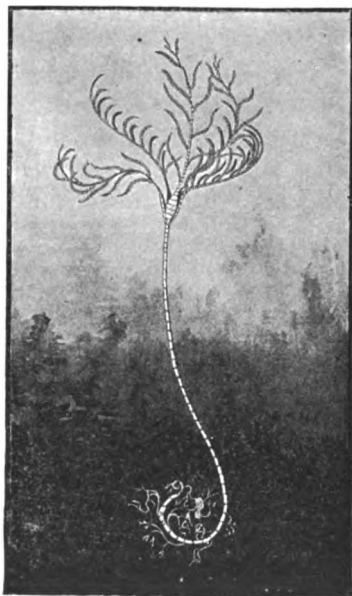


FIG. 180.—A crinoid (*Rhizocrinus loxoten-sis*). A deep-sea animal which lives, fixed plant like, at the bottom of the ocean.

sea, and in some forms these shining appendages are highly developed. In one form (*Æthoprora*) a luminous body covers the end of the nose, like the head-light of an engine. In another (*Ipnope*) the two eyes themselves are flattened out, covering the whole top of the head, and are luminous in life. Many of these species have excessively large teeth, and some have been known to swallow animals actually larger than themselves. Those which have lantern-like spots have always large eyes.

The deep-sea fishes, however fantastic, have all near relatives among the shore forms. Most of them are degenerate representatives of well-known species—for example, of eels, cod, smelt, grenadiers, sculpin, and flounders. The deep-sea crustaceans and mollusks are similarly related to shore forms.

The third great subdivision of marine animals is the *littoral* or shore group, those living in water of moderate depth, never venturing far into the open sea either at the surface or in the depths. This group shades into both the preceding. The individuals of some of the species are excessively local, remaining their life long in tide pools or coral reefs or piles of rock. Others venture far from home, and might well be classed as pelagic. Still others ascend rivers either to spawn (anadromous, as the salmon, shad, and striped bass), or for purposes of feeding, as the robalo, corvina, and other shore-fishes of the tropics. Some live among rocks alone, some in sea-weed, some on sandy shores, some in the surf, and some only in sheltered lagoons. In all seas there are fishes and other marine animals, and each creature haunts the places for which it is fitted.

CLASSIFICATION OF ANIMALS *

In this diagram of classification every animal referred to in this book, either by its vernacular or its scientific name, is assigned to its proper class and branch. Of the species mentioned by their scientific names, only the genus name is given in this list.

KINGDOM · ANIMALIA

BRANCH I. PROTOZOA

CLASS I. **Rhizōp'oda.**

Amœ'ba, *Globigeri'næ*, *Rădiolă'ria*.

CLASS II. **Mycōstozō'a.**

CLASS III. **Mastigōph'ora.**

Volvocin'æ, *Gō'nium*, *Păndori'na*, *Eudori'na*, *Vōl'vœx*.

CLASS IV. **Spōrozō'a.**

Grēgari'na.

CLASS V. **Infusō'ria.**

Păramœ'cium, *Vorticēl'la*.

BRANCH II. PORĪF'ERA

CLASS I. **Porifera.**

Sponges, *Călcōlŷn'thus*, *Prophysē'ma*, *Spongil'la*, *Spon'gia*, *Ch'ona*.

BRANCH III. CĒLĒN'TERĀ'TA (sē-lēn-te-ră'-ta)

CLASS I. **Hŷdrozō'a.**

Hŷ'dra, *Eucō'pe*, *Siphōnōph'ora*, *Phŷsōph'ora*, *Obē'lia*, sea-anēm'-one, pōl'yp, *Phŷsă'lia*, *Părapăg'urus*.

CLASS II. **Scŷphozō'a** (sī-fō-zō'-a).

Jelly-fish, *Liz'zia*.

CLASS III. **Actinozō'a.**

Cōr'als, *Mētrī'dium*.

CLASS IV. **Ctēnōph'ora** (tēn-ōph'-o-ra).

* The arrangement of branches (or phyla) and classes here used is that adopted in Parker and Haswell's Text-Book of Zoology (1897).

BRANCH IV. PLÄTYHĚLMĚN'THES

CLASS I. **Turbellā'ria.***Planā'ria.*CLASS II. **Trématō'da.**CLASS III. **Céstō'da.***Tape-worm, Tē'nia, Lig'ula, flat-worm.*APPENDIX TO PLATYHELMINTHES—CLASS **Nemertīn'ea.**

BRANCH V. NĚMATHĚLMĚN'THES

CLASS I. **Nématō'da.***Syn'gamus, round-worm, Trichī'na, Bōthriocēph'alus, pup-worm, Uncinā'ria.*CLASS II. **Acanthocēph'ala.**CLASS III. **Chætōg'natha (kē-tōg'-na-tha).**

BRANCH VI. TROCHELMĚN'THES

CLASS I. **Rotif'era.***Rotatō'ria.*CLASS II. **Dinoph'lea.**CLASS III. **Gastrōt'richa.**

BRANCH VII. MĚLLUSCOI'DA

CLASS I. **Pōlyzō'a.**CLASS II. **Phōrō'nida.**CLASS III. **Brāchiōp'oda.**

BRANCH VIII. ĚCHĚNĚDĚR'MATA

CLASS I. **Asteroi'dea.***Starfish.*CLASS II. **Ophiuroi'dea.**CLASS III. **Ěchinoi'dea.***Sea-urchin.*CLASS IV. **Hōlothuroi'dea.***Sea-cucumber.*CLASS V. **Crinoi'dea.***Grinoid, Rhizōcri'nus.*CLASS VI. **Cytoi'dea.**CLASS VII. **Blāstoi'dea.**

BRANCH IX. ANNULĀ'TA

CLASS I. *Chætōp'oda* (kē-tōp'-o-da).

Earth-worm.

APPENDIX TO THE CHÆTOPODA—CLASS *Mýzostōm'ida*.CLASS II. *Gēphyrē'a* (jēf-e-rē'-a).CLASS III. *Archī-annēl'ida*.CLASS IV. *Hīrudīn'ea*.

BRANCH X. ARTHRŌP'ODA

CLASS I. *Crustā'cea*.

Lobster, cray-fish, crab, barnacle, *Lē'pas*, hermit-crab, *Pāg'urus*, pea-crab, *Pinnothē'res*, *Epizoān'thus*, fish-lice, whale-lice, *Saccu-lī'na*, *Lernæō'cera*, prawn, *Penē us*.

APPENDIX TO CRUSTACEA—CLASS *Trilobī'ta*.CLASS II. *Ōnychōph'ora*.CLASS III. *Mýriāp'oda*.

Cēn'tipēd.

CLASS IV. *Insēc'ta*.

Water-beetle, water-bug, canker-worm moth, bee, white ant, cockroach, mosquito, weevil, grasshopper, caterpillar, butterfly, katydid, beetle, *Dip'tera*, *Lēpidōp'tera*, monarch butterfly, *Anō'sia*, *Cu'tex*, *Melān'oplus*, May-fly, locust, cottony-cushion scale, *Icē'rya*, lady-bird, *Vēdā'lia*, praying-horse, *Mān'tis*, *Sēr'phus*, *Cēcrō'pia*, gall insect, *An'dricus*, mole-cricket, *Grýllotāl'pa*, *Hýdrōph'ilus*, *Priō'nus*, *Camponō'tus*, plant-lice, *Āph'idæ*, *Cōc'eidæ*, *Āphis*-lion, ant, *Ec'iton*, termite, bumble-bee, carpenter-bee, *Andrē'na*, *Halic'tus*, yellow-jacket, hornet, *Vēs'pa*, wasp, *Ā'ta*, bird-lice, *Mallōph'aga*, flea, louse, *Pedīc'ulus*, *Lipeu'rus*, *Hýmenōp'tera*, ichneumon fly, *Thalēs'sa*, horn-tail, *Trēmex*, *Polīs'tes*, *Stýlōp'idæ*, *Stý'lops*, red orange-scale, toad-bug, *Gāl'gulus*, inch-worm, span-worm, geometrid, walking-stick, *Diapherōm'era*, *Phýl'lum*, meadow brown, *Grāp'ta*, *Kāl'līma*, sphinx-moth, tomato-worm, *Phlēge-thōn'tius*, puss-moth, *Cerū'ra*, viceroy butterfly, *Bāsilar'chia*, *Danā'idæ*, *Helicōn'idæ*, *Piēr'idæ*, *Papliōn'idæ*, *Syr'phidæ*, flower-flies, tree-hopper, *Membrāc'idæ*, *Hemīp'tera*, *Sau'ba* (saw'-ba), carrion-beetle, *Callosā'mia*, *promē'thea*, cricket, *cicā'da*, dragon-fly, *Cynīp'idæ*, Hessian-fly, mud-dauber, *Lerē'ma*, *Erýn'nis*, skipper butterfly, *Schistocēr'ca*.

CLASS V. *Arāch'nida*.

Tardīg'rada, bear-animalcule, scorpion, *Lycōs'idæ*, tick, itch-mite, *Sarcōp'tes*, spider, trap-door spider, turret-spider, *Cten'tza*.

BRANCH XI. MÖLLÜS'CA

CLASS I. *Pölecö'p'oda*.Clam, pond-mussel, *Li'ma*.CLASS II. *Amphineu'ra*.CLASS III. *Gaströp'oda*.Pond-snail, *Lymnæ'us*, whelk.APPENDIX TO THE GASTROPODA—CLASS *Scaphöp'oda* AND *Rhō'dope*.CLASS IV. *Cēphalöp'oda*.

BRANCH XII. CHORDĀ'TA

SUB-BRANCH I. *Addloohör'da*. CLASS *Adelochorda*.SUB-BRANCH II. *Urochor'da*. CLASS *Urochorda*.Sea-squirts, *Tunicā'ta*.SUB-BRANCH III. *Vertebrā'ta*. DIVISION A. *Acrā'nia*. CLASS *Acra'nia*. DIVISION B. *Orāniā'ta*.CLASS I. *Oyolostōm'ata*.CLASS II. *Pis'ces* (pis'sēz).

Codfish, sculpin, skate, lady-fish, *Ārbula*, sword-fish, *Xēph'ias*, flounder, *Platōph'rys*, *Salanz*, *Cōl'tus*, blob, miller's-thumb, conger-eel, *Rēm'ora*, *Exocē'tus*, flying-fish, *Cypselu'rus* (sip-se-lu-rus), deep-sea angler, lantern-fish, *Corynōl'ophus*, *Echōs'toma*, *Æthōph'ora*, nokee, scorpion-fish, *Emmydrich'thys*, mad-tom, *Schilbeōdes*, cat-fish, horned pout, toad-fish, sting-ray, globe-fish, porcupine-fish, torpedo, electric eel, electric cat-fish, star-gazer, electric ray, *Urdōl'ophus*, *Dē'odon*, *Narci'nē*, *Rā'ja*, black-fish, mud-fish, trout, *Sāl'mo*, chub, horned dace, Echeneididæ *Amphiprion*, *Nō'meus*, hag-fish, *Myx'ine*, *Heptatrē'ma*, *Polistotrē'ma*, lamprey, *Oligocōl'tus*, mouse-fish, lava-fish, *Pterophrŷne*, pipe-fish, *Phyllōp'teryx*, anglers, *Lō'phius*, *Antennā'rius*, Ceratiide, minnow, mackerel, sucker, salmon, shad, alewife, sturgeon, striped bass, quīn'nat, eel, sun-fish, stickle-back, carp, cutlass-fish, rainbow darter, channel-cat, *Au'xis*, tunny, dolphin, opah, shark, *Æthoprō'ra*, *Ip'nops*, cod, smelt, grenadier, rōb'alo, corvī'na, *Chōlogūs'ter*, *Tŷphlīch'thŷs*, blind-fish.

CLASS III. *Amphīb'ia*.Toad, frog, salamander, tree-frog, *Hŷ'la*.CLASS IV. *Reptīl'ia*.

Tortoise, snake, horned toad, *Phrŷnōsō'ma*, rattlesnake, lizards, *An'olis*, chameleon, Gila monster, *Hēlodēr'ma*, *Elaps*, coralīl'los, *Lāmpropēl'tis*, *Osceōla*, alligator.

CLASS V. A'ves.

Bird-of-paradise, peacock, pheasant, robin, pigeon, chicken, eagle, vulture, guil'lemot (gîl'-e-môt), murre (mûr), auk, ful'mar, pêt'rel, sparrow, bluebird, woodpecker, owl, *Colûm'ba*, pelican, *Melanêr'pes*, cormorant, meadow-lark, warbler, turkey, blue jay, *Aythya*, *Cyanocitta*, *Uria*, cow-bird, cuckoo, parrot, ptarmigan, whippoorwill, *Antrôs'tomus*, gull, tern, fly-catcher, bittern, mocking-bird, shrike, bobolink, goose, humming-bird, oriole, puffin, tailor-bird, king-bird, nightingale, starling, skylark, passenger-pigeon, ouzel (ooz'-el), linnet, tanager, vireo, wood-warbler, *Phalacro'corax*, *Trich'ilus*, *Ornithô'tomus*, *Psaltîp'arus*.

CLASS VI. Mammâ'lia.

Horse, ram, fur-seal, rabbit, cat, ox, tiger, lion, sheep, elephant, whale, bear, wolf, squirrel, lêm'ming, fox, dog, weasel, stoat, reindeer, otter, ant-eater, gîraffe', skunk, porcupine, hedgehog, armadillo, *Callorhî'nus*, sea-lion, deer, buffalo, kangaroo, *Mâc'ropus*, duck-bill, Mön'otrême, monkey, gopher, elk, bison, prairie-dog, big-horn, hare, antelope, black-tail deer, hound, mole, hyena, mice, rodent, woodchuck, jack-rabbit, *Macâ'cus*, *Cercopîth'ecus*, beaver, wood-rat, pocket-gopher, coyo'ta, civet-cat, flying-fox, môn'goose, sea-cow, *Vûl'pes*, walrus, musk-ox, ape, rhinôc'eros, hippopôt'amus, leopard, ass, lē'mur, *Trich'êchus*, manatee, *Lē'pus*, *Odôbœ'nus*, *Lē'mur*.

GLOSSARY

[Only those terms are defined in this glossary that are not explained in the text. In the case of the terms defined or explained in the text, reference is made to the number of the paragraph in which the explanation occurs. The pronunciation of the vernacular and scientific names of the animals mentioned in the text is given in the Classification.]

Ābomā'sum : 42.

Adaptation : 67, 74.

Albuminous : said of substances containing albumen.

Alimēn'tary canal : 42.

Alluring coloration : 111.

Altru'ial : 79.

Altruis'tic instinct : 129.

Amœ'boid : having the changing form of an Amœba.

Anăd'romous : said of fishes that go from the sea up rivers to lay their eggs.

Anăt'omy : 39.

Animāl'cule : an animal of microscopic smallness.

Antē'næ : the "feelers," the most anterior pair of appendages of insects and insect-like animals; situated on the head, and the seat of organs of special sense.

Ān'thropoid : man-like.

Ā'nus : 42.

Appēn'dix vermifor'mis : 82.

Artificial selection : 72.

Assim'ilate : to receive food and transform it into a homogenous part of the body substance.

Ātoll' : a ring-shaped coral island nearly or quite inclosing a lagoon.

Āt'rophy : a stoppage of the growth or development of a part or organ.

Auditory : referring to the sense of hearing.

Autōm'atism : the state of being automatic; involuntary action.

Bassā'ian : 160.

Biōl'ogist : student of animals and plants.

Blās'tōderm : 50.

Blās'tula : 50.

Budding : the process of reproduction among animals in which a small part of the body substance of an animal grows out from the surface, separates from the parent, and develops into a new individual.

Cœ'cum (sē-kum) : 42.

Carnīv'orous : flesh-eating.

Cāt'arrhīne : nostril downward; said of the narrow-nosed Old-World monkeys.

Cell : 2.

Cēl'lulose : a peculiar compound insoluble in all ordinary solvents, forming the fundamental material of the structure of plants, and also contained in the mantle of tunicates.

Chr'tin : 57.

Chlō'rophŷll : 18.

Chrō'matophore : a color-bearing granule or sac.

Chrō'mosome : 2.

Chrŷ's'alis : 57.

Chŷ'le : 42.

Cl'ia : 5.

Cleavage : 50.

Clō'lon : 42.

Commēn'salism : 90.

Cōm'munal : 83.

Conjugā'tion : 5.

Contractile vacuole : a vacuole that dilates and contracts regularly, and is supposed to have an excretory function.

Cŷst : 98.

Cŷtoplasm : 2.

Degeneration : 95.

Development : 46.

Differentiation : the setting apart of special organs for special work; progressive change from general to special; specialization.

Digestion : the process of dissolving and chemically changing food so that it can be assimilated by the blood and furnish nutriment to the body.

Dimor'phism : 24.

Divertic'ulum : a blind pouch arising from another larger pouch. 44.

Duodē's'num : 42.

Ėc'tōblast : 50.

Ėc'tōderm : 20.

Egg-cell : 20.

Egois'tic instinct : 129.

Embryōl'ogy : 39.

Embryōn'ic : 49.

Ėn'dōblast : 50.

Ėn'dōderm : 20.

Envi'ronment : an organism's surroundings taken collectively.

Ėx'cretory : referring to excretion, as excretory organs, the organs which get rid of waste matter in the animal body.

Fau'na (fawna) : 157.

Fertilized egg : 20.

Fis'sion : 4.

Flagē'l'a : 18.

Function : 37.

Gān'glio (pl. ganglia) : a nerve-center composed of an aggregation of nerve-cells.

Gās'trula : 50.

Gēm'mule : 20.

Generalization : 41.

Gēōl'ogist : student of the structure and history of the earth.

Grēgā'rious : 87.

Growth : 46.

Habit : 139.

Herbiv'orous : plant-eating.

Herēd'ity : 54.

Hermāphrodīt'ic : 35.

Hibernā'tion : passing the winter in a death-like sleep.

Hōmoge'neous : of the same composition or structure throughout.

Īleum : 42.

Inorganic : not being nor having been a living organism ; not organic.

Insectiv'orous : insect-eating.

Instinct : 128.

Intellect : 139.

Intercē'l'ular : outside of and between the cells.

Jefu'num : 42.

Lagoon' : a pool or lake; the still water inclosed within an atoll.

Lar'va : 57.

Lēpidōp'terous : referring to the Lepidoptera, or moths and butterflies.

Lit'toral : 160.

Lu'men : the cavity of a tubular organ. 44.

Medu'sa : 24.

Mēg'alops : 59.

Mēs'oderm : 20.

Mētāb'olism : the act or process by which dead food is built up into living matter, and living matter is broken down into simpler products within a cell or organism.

Mētamor'phosis : 56.

Migra'tion : 70.

Millimeter : about one twenty-fifth of an inch; a term used in the metric system of measure.

Mim'icry : 112.

Mind : 140.

Molt : 57.

Mōnōg'amous : said of animals in which a male mates with only a single female.

Multiplication : used in the text usually synonymously with reproduction.

Mŷrmeōph'ilous : said of insects which are found inhabiting the nests of ants.

Natural selection : 70.

Nō tochord : an elastic rod, or row of cells, formed in the early embryo of chordate animals (including all the vertebrates and some others), which lies below the dorsal nervous tube and above the ventral alimentary tube.

Nu'cleus (pl. *nuclēi*) : 2.

Œsōph'agus : 42.

Olfactory : referring to the sense of smell.

Omā'sum : 42.

Organ : 37.

Organic : referring to the matter of which animals and plants are composed.

Organism : a living being, plant or animal.

Orientā'tion : 95.

O'tolith : 121.

Papil'la (pl. **papillæ**): a small nipple-like process, as the papillæ of the skin or tongue.

Parasite: 93.

Parthēnogēn'esis: 35.

Pēlāg'ic: inhabiting the surface of mid-ocean. 160.

Phar'ynx: 42.

Phy'niōl'ogy: 39.

Plāt'yrrhīne: broad-nosed; said of the New-World monkeys.

Plu'teus: 59.

Pol'y'g'amous: said of animals in which a single male mates with several females: 35.

Pōlymor'phism: 24.

Pōl'yp: 21.

Post-embryonic: 49

Præcō'cial (prē-co'-shal): 79.

Prēd'atory: feeding on other animals.

Prō'polis: 84.

Protective resemblance: 107.

Prō'toplaam: 2.

Prō'ventrīc'ulus: 42.

Pseu'dopod: 4.

Psy'chic: 140.

Pu'pa: 57.

Reason: 139.

Recognition mark: 77, 115.

Rēc'tum: 42.

Reflex action: 127.

Reproduction: 67.

Respiration: 4.

Retic'ulum: 42.

Rēt'ina: 123.

Ru'men: 42.

Ru'minant: 42.

Sal'va: 42.

Sensation: 67.

Sensorium: 126.

Sil'ica: the mineral of which quartz, sand, flint, etc., are composed.

Spawn, v.: to lay eggs.

Specialization: 41.

Species: 151.

Sperm cell: 20.

Spir'acle: one of the breathing openings of an insect situated on the side of the abdomen or thorax.

Spon'gin: 20.

Stimulus (pl. *stimuli*): that which excites action in plant or animal tissue.

Strā'ta: layers, usually said of rocks.

Stridulā'tion: 122.

Sub-species: 151.

Symbiō'sis: 90.

Tactile: referring to the sense of touch. 118.

Tadpole: 58.

Tēn'tacle: a protruding flexible process or appendage, usually of the head of invertebrate animals, being used as an organ of touch, prehension, or motion.

Tērmitōph'ilous: said of insects inhabiting the nests of termites.

Vāc'ule: a minute cavity containing air, water, or a chemical secretion of the protoplasm, found in an organ, tissue, or cell.

Vestig'ial: 82.

Vis'cera: the organs in the great cavities of the body, commonly used for the organs in the abdominal cavity.

Yōlk (yōk): 48.

Zoō'a: 59.

Zōogeōg'raphy: 147.

Zō'oid: one of the more or less independent members of a colonial or compound organism.

Zōōl'ogist: a student of animals.

INDEX

- Abomasum, 68.
Actinocephalus oligacanthus (ill.), 14.
 Adaptations, 118, 123; classification of, 123; concerned with surroundings, 143; degree of structural change in, 146; for defense of young, 137; for rivalry, 135; for self-defense, 128; for securing food, 125; origin of, 123.
 Agassiz's cave-fish (illus.), 282.
Albula vulpes, metamorphosis of (illus.), 98.
 Alimentary canal, 66; of cockroach (illus.), 73; of earthworm (illus.), 71; of flatworm (illus.), 70; of Holothurian (illus.), 70; of mussel (illus.), 72; of *Obelia* (illus.), 69; of ox (illus.), 67; of *Planaria* (illus.), 70; of sea-cucumber (illus.), 70.
 Alligator (illus.), 290.
 Alluring coloration, 216.
 Alternation of generations, 42.
 Altricial, 140.
Amæba, 5; multiplication of (ill.) 53.
Amæba polypodia (illus.), 8.
 Anatomy, 64.
Andrena, nest of (illus.), 160.
Andricus californicus, galls of (illus.), 143.
 Angler, deep-sea (illus.), 124.
 Animals, life of simplest, 1; many-celled, 2; one-celled, 2; slightly complex, 24.
Anosia plexippus, metamorphosis of (illus.), 92; mimicked by *Basilarchia archippus* (illus.), 219.
 Antenna of cray-fish (illus.), 233; of leaf-eating beetle (illus.), 230.
 Antennæ, specialized, of promethea moth (illus.), 231.
Antrostomus vociferus (illus.), 203.
 Ants (illus.), 155.
 Anus, 68.
 Appearance, terrifying, 212.
 Arctic realm, 297.
 Area, faunal, 296.
 Artificial selection, 120.
 Auditory organ of cray-fish (illus.), 233; of cricket (illus.), 234; of grasshopper (illus.), 234; of mollusk (illus.), 233; of mosquito (illus.), 235.
 Auditory organs, 232.
 Australian realm, 303.
Aythya (illus.), 137.
 Barbadoes earth, 19.
 Barnacle, adult and larva (illus.), 195; metamorphosis of (illus.), 101.

- Barrier, mountains a, to distribution, 298; sea a, to distribution, 288; temperature a, to distribution, 290.
- Barriers affecting fresh-water animals, 294; effect of, 288; species debarred by, 274; to distribution, character of, 288.
- Basilarchia archippus* mimicking *Anosia plexippus* (illus.), 219.
- Bassalian fauna, 305.
- Beavers, nest of (illus.), 269.
- Beetle, larva of (illus.), 146.
- Beetles, lady-bird (illus.), 214.
- Bird, egg of (illus.), 79.
- Bird-louse (illus.), 188.
- Bird of paradise (illus.), 58.
- Birds, nest-making habits of, 264.
- Birth, 78.
- Bittern, nestlings of (illus.), 246, 247.
- Blastoderm, 82.
- Blastula, 82.
- Blue jay (illus.), 138.
- Brain, 241.
- Budding, 13.
- Bumble-bee, 159, (illus.), 161.
- Bush-tit, nest of California (illus.), 270.
- Butterfly, egg of (illus.), 79; monarch, metamorphosis of (illus.), 92.
- Cæcum, 68.
- Calcolynthus porimigenius* (illus.), 33.
- Calf, taste buds of (illus.), 229.
- Callorhinus alascanus* (illus.), 136.
- Camponotus* (illus.), 155.
- Canadian skipper butterfly, distribution of (illus.), 273.
- Canal, alimentary, 66.
- Cankerworm-moth (illus.), 59.
- Care of young of mammals, 268.
- Carpenter-bee, nest of (illus.), 160.
- Caterpillar parasitized (illus.), 189, (illus.), 190.
- Cave blind-fish (illus.), 282.
- Ceanothus (illus.), 141.
- Cell, animal, 2; egg, 21, 56; plant, 2; products, 3; wall, 3.
- Cells, brood, of honey-bee (illus.), 152; nerve, 240; reproductive, 29, 55.
- Cellulose, 24, 27.
- Centiped (illus.), 130.
- Cerura, larva of (illus.), 216.
- Chalk, 18.
- Chick, embryonic stages of (illus.), 87.
- Chitin, 91.
- Chlorophyll, 24.
- Chologaster agassizi* (illus.), 282.
- Chologaster avelus* (illus.), 282.
- Chromatophore, 24.
- Chromosome, 3.
- Chrysalid of butterfly, showing protective resemblance (illus.), 206.
- Chrysalis, 93.
- Chyle, 68.
- Cilia, 9.
- Cleavage, 82.
- Climate, influencing distribution, 291; instincts of, 248.
- Clouded skipper butterfly, distribution of (illus.), 273.
- Coccidium oriforme* (illus.), 14.
- Cockroach, alimentary canal of (illus.), 73; egg case of (illus.), 140.
- Cocoon of *Cecropia* moth (illus.), 141.

- Colon, 66.
 Colonial jelly-fishes, 45; Protozoa, 24.
 Colony, 81.
 Color, 222.
 Coloration, alluring, 216.
 Colors, warning, 212.
 Commensalism, 172, 173.
 Communal life, 168; advantages of, 170.
 Communities, animal, 149.
 Conditions, primary, of animal life, 106.
 Conjugating cells, 28.
 Conjugation, 11, 27, 55.
 Contractile vacuole, 10.
 Coral, brain, 45; island (illus.), 44; organ-pipe (illus.), 45; red, 45.
 Corals, 37-43.
Corynolophus reinhardti (illus.), 124.
 Cottony cushion scale (illus.), 142.
 Courtship, instincts of, 248.
 Crab, metamorphosis of (illus.), 97; with sea-anemone (illus.), 177.
 Cray-fish, auditory organ of (illus.), 283.
 Cricket, auditory organ of (illus.), 284.
 Cricket, mole (illus.), 146.
 Crinoid (illus.), 305.
 Crop, 71.
 Crowd of animals, 114.
 Crustaceans, adults and larvæ (illus.), 195.
Cteniza californica, nest of (illus.), 261.
Cyanocitta cristata (illus.), 138.
 Cycle, life, 78.
 Cypselurus (illus.), 131.
 Cytoplasm, 3.
 Dead-leaf butterfly (illus.), 211.
 Death, 108.
 Deep-sea angler (illus.), 124.
 Deer, horns of (illus.), 148.
 Defense of the young, 137.
 Degeneration, causes of, 197, 198; human, 200; through quiescence, 193.
 Desiccation, 104.
 Development, 78; continuity of, 83; divergence of, 84; embryonic, 80; first stages in (illus.), 81; laws of, 86; metamorphic, 90; of flounder (illus.), 100; of locust (illus.), 91; of vertebrates, (illus.), 87; post-embryonic, 80; significance of facts of, 89.
Diapheromera femorata (illus.), 209.
 Differentiation, 41; of structure, 64.
 Dimorphism, 42; sex, 58.
Diodon hystrix (illus.), 134.
 Dismal Swamp fish (illus.), 282.
 Distribution, character of barriers, to, 288; geographical, 272; influenced by climate, 291; laws of, 274; modes of, 296; mountains a barrier to, 293; of Canadian Skipper butterfly (illus.), 273; of clouded Skipper butterfly (illus.), 273; of *Erynnis manitoba* (illus.), 273; sea a barrier to, 288; temperature a barrier to, 290.
 Diverticula, 74.
 Division of labor, 22, 168.
 Dog, pointer (illus.), 256.
 Dragon-fly, eye of (illus.), 239.
 Duck, family (illus.), 137.
 Duodenum, 68.
 Duration of life, 101.

- Earthworm, alimentary canal of (illus.), 71.
 Ectoblast, 82.
 Ectoderm, 33.
 Egg case of Californian barn-door skate (illus.), 140; cockroach (illus.), 140.
 Egg cell, 21, 56.
 Egg, fertilized, 35; of bird (illus.), 79; of butterfly (illus.), 79; of fish (illus.), 79; of katydid (illus.), 79; of skate (illus.), 79; of toad (illus.), 79.
 Electric ray, (illus.), 135.
 Embryology, 64.
 Embryonic development, 80; of the pond snail, 81.
Emmydrichthis vulcanus (illus.), 132.
 Endoblast, 82.
 Endoderm, 33.
 Environment, instincts of, 248.
Epizoanthus paguriphilus, with sea-anemone (illus.), 177.
Erynnis manitoba, distribution of (illus.), 273.
Eucope (illus.), 42.
Eudorina, 27.
Eudorina elegans (illus.), 28.
Exocætus (illus.), 131.
 Eye of dragon-fly (illus.), 239; of jelly-fish (illus.), 238.
 Fauna, 296; bassalian, 305; littoral, 306; pelagic, 304.
 Faunal areas of the sea, 304.
 Feeding habit of Californian wood-pecker (illus.), 128, 129; of *Melanerpes formicivorus bairdii* (illus.), 128, 129; instincts of, 244.
 Female, 57.
 Fish, egg of (illus.), 79; embryonic stages of (illus.), 87; -louse (illus.), 188.
 Fishes, man-of-war (illus.), 175; nest-making habits of, 264.
 Fission, 9; binary, 54.
 Flagella, 25.
 Flagellata, 24.
 Flatworm, alimentary canal of (illus.), 70.
 Flounder, development of (illus.), 100; wide-eyed (illus.), 100.
 Flying fishes (illus.), 131.
 Food, adaptations for securing, 125; necessary to animal life, 106.
 Form, primitive, 20.
 Fossil, 18.
 Fresh-water animals, barriers affecting, 294.
 Function, 63.
 Fur seal (illus.), 136.
 Galapagos Islands, animals of (illus.), 278; locusts of (illus.), 280.
 Gall, giant, of white oak (illus.), 143.
 Galls, insect, on leaf (illus.), 144.
 Gapes, worm which causes, 60.
 Gastrula, 82.
 Gemmule, 35.
 Generalization, 66.
 Generation, spontaneous, 51.
 Generations, alternation of, 51.
 Geographical distribution, 272.
 Geometrical larva on branch (illus.), 209.
Gerrhonotus scincicauda (illus.), 204.
 Giraffe (illus.), 126.
 Gizzard, 71.

- Globigerina-ooze*, 18.
Globigerina, 16.
Gonium, 25-30.
Gonium pectorale (illus.), 25.
 Grasshopper, auditory organ of (illus.), 234.
 Green-leaf insect (illus.), 210.
Gregarina, 13, 182.
Gregarina polymorpha (illus.), 14.
Gregarinidae, 14.
 Gregariousness, 163.
 Growth, 78.
Gryllotalpa (illus.), 146.

 Habit, 251.
 Habitat, relation of species of, 283.
 Habits, domestic, 257.
 Habits, nest-making, of birds, 264; of fishes, 264; of insects, 262; of invertebrates, 258; of spiders, 259; of vertebrates, 264.
 Hearing, sense of, 232.
Heliosphæra actinota (illus.), 19.
 Heredity, 89.
 Hermaphroditism, 60.
 Hermit-crab, with the sea-anemone (illus.), 176.
 Hibernation, 103.
 Hiving honey-bees (illus.), 154.
 Holothurian, alimentary canal of (illus.), 70.
 Homes, 257.
 Honey-bee (illus.), 150; adult and larva (illus.), 83; leg of (illus.), 151: life history of, 149.
 Honey-bees, hiving a swarm of (illus.), 154.
 Host, relation of parasite to, 179.
 Human degeneration, 200.
 Humming-bird, nest of rufus (illus.), 265, 266.
Hydra, 37.
Hydra vulgans (illus.), 38.
Hydrophilus (illus.), 146.
Hyla regilla (illus.), 145.

Icerya and *Vedalia*, 121.
Icerya purchasi (illus.), 142.
 Ileum, 68.
 Individual, 31.
 Indo-African realm, 301.
 Inorganic matter, 112.
 Insect galls on leaf (illus.), 144.
 Insects, metamorphosis of, 90; nest-making habits of, 262; parasitic, 188.
 Instinct, 242.
 Instincts, altruistic, 243; classification of, 243; concerned with care of the young, 250; egoistic, 243; of climate, 248; of courtship, 248; of environment, 248; of feeding, 244; of play, 247; of reproduction, 249; of self-defense, 245; variability of, 251.
 Intellect, 254.
 Intestine, 68.
 Invertebrates, nest-making habits of, 258.
 Irritability, 8, 240.
 Island, coral (illus.), 44.
 Itch-mite (illus.), 192.

 Jack-rabbits, showing variation (illus.), 281.
 Jay, Canada (illus.), 138.
 Jejunum, 68.
 Jelly-fish, eye of (illus.), 238.
 Jelly-fishes, 37; colonial, 45.

Kallima (illus.), 211.
 Kangaroo (illus.), 139.
 Katydid, egg of (illus.), 79.
 Lady-bird beetles (illus.), 214.

- Lady-fish**, metamorphosis of (illus.), 98.
- Larva**, 92; of the mosquito, 93; of butterfly pupating (illus.), 94; of the honey-bee, 152.
- Leaf-cutting ant** mimicked by tree-hoppers (illus.), 220.
- Lemur** (illus.), 302.
- Lemur varius* (illus.), 302.
- Lemurian realm**, 302.
- Lepas*, adult and larva (illus.), 195; metamorphosis of (illus.), 101.
- Lerema accius*, distribution of (illus.), 273.
- Lernæocera* (illus.), 188.
- Life cycle**, 78.
- Life**, communal, 168; duration of, 101; primitive, 21; processes, 21; social, 149.
- Light**, influence of, on animals, 237.
- Lipeureus densus* (illus.), 188.
- Littoral fauna**, 306.
- Lizard**, alligator (illus.), 204.
- Lizzia koellikeri*, eye of (illus.), 238.
- Locust**, post-embryonic development of (illus.), 91.
- Locusts of Galapagos Islands** (illus.), 280.
- Louse**, sucking (illus.), 188.
- Macropus rufus*, 139.
- Mad Tom** (illus.), 132.
- Male**, 57.
- Mammals**, care of young of, 268.
- Manatee** (illus.), 277.
- Man-of-war**, Portuguese (illus.), 175.
- Mantis* (illus.), 127.
- Many-celled animal**, 2.
- Marine Protozoa**, 15.
- Marks**, recognition, 22, 129, 228.
- Medusa**, 41.
- Megalops**, 97.
- Melanerpes formicivorus bairdii*, feeding habit of (illus.), 128, 129.
- Membracidae** mimicking *Sauba* ant (illus.), 220.
- Mesoderm**, 33.
- Metamorphosis**, 90; of *Albula vulpes* (illus.), 98; of *Anosia plexippus* (illus.), 92; of barnacle (illus.), 101; of butterfly (illus.), 92; of crab (illus.), 97; of insects, 90; of lady-fish (illus.), 98; of *Lepas* (illus.), 101; of mosquito (illus.), 93; of sea-urchin (illus.), 96; of sword-fish (illus.), 99; of toad, 94. (illus.), 95; of *Xiphias gladius* (illus.), 99.
- Metazoa**, 32.
- Metridium dianthus* (illus.), 43.
- Micro-organism**, 16.
- Migration of lemming**, 118; of locust, 118.
- Mimickry**, 218.
- Mind**, 255.
- Mining-bee**, nest of (illus.), 160.
- Molt**, 91.
- Monarch butterfly** (illus.), 219; mimicked by Viceroy butterfly (illus.), 219.
- Monogamy**, 135.
- Mosquito**, auditor organ of (illus.), 235; head of (illus.), 127; metamorphosis of (illus.), 93; young stages of (illus.), 147.
- Moth**, cankerworm (illus.), 59.
- Mountains as barriers to distribution**, 293.
- Mouth parts of mosquito** (illus.), 127.

- Mouse-fish in gulf-weed (illus.), 208.
 Mt. Orizaba (illus.), 300.
 Multiplication, 50; of animals, 114; simplest method of, 53; slightly complex methods of, 54.
 Murres, Pallas's (illus.), 165.
 Mussel, alimentary canal of (illus.), 72.
 Mutual aid, 163.

 Narcine brasiliensis (illus.), 135.
 Natural selection, 117.
 Neotropical realm, 301.
 Nerve cells, 240.
 Nerve fibers, 240.
 Nest-making habits of birds, 264; of fishes, 264; of insects, 262; of invertebrates, 258; of spiders, 259; of vertebrates, 264.
 Nest of Baltimore oriole (illus.), 267; of beavers (illus.), 269; of Californian bush-tit (illus.), 270; of *Cteniza californica* (illus.), 261; of pocket-gopher (illus.), 271; of rufus humming-bird (illus.), 265, 266; of tailor-bird (illus.), 268; of trap-door spider (illus.), 261; of turret-spider (illus.), 262.
 Nokee (illus.), 132.
Nomeus gronovi (illus.), 175.
 North Temperate realm, 299.
 Nuclear membrane, 3.
 Nucleus, 3.

Obelia, alimentary sac of (illus.), 69.
 Oesophagus, 67.
 Omasum, 67.
 One-celled animals, 2.
 Organ, 63; auditory, of cray-fish (illus.), 233; of cricket (illus.), 234; of grasshopper (illus.), 234; of mosquito (illus.), 235; of mollusk (illus.), 233.
 Organic matter, 112.
 Organs, auditory, 232; of smell, 229; of sound-making, 235; of taste, 228; of touch, 226; specialization of, 66; vestigial, 147.
 Oriole, Baltimore, nest of (illus.), 267.
Ornithotomus sutorius, nest of, 268.
 Osprey Falls (illus.), 285.
 Otolith, 232.
 Ox, alimentary canal of (illus.), 67.
 Oxygen, necessary to animal life, 107.

Pagurus (illus.), 176.
Pandorina, 26.
Pandorina sp. (illus.), 26.
Pandorina morum (illus.), 27.
Papilio, chrysalid of (illus.), 205.
 Papilla, tactile, of skin of man (illus.), 227.
 Papillæ, 67.
Paramæcium, 9.
Paramæcium aurelia (illus.), 10.
Paramæcium caudatum (illus.), 11.
Paramæcium plutonium (illus.), 11.
 Parasite of caterpillar (illus.), 190; relation to host, 179.
 Parasites, simple structure of, 181.
 Parasitism, 179; kinds of, 180.
 Parthenogenesis, 60.
 Patagonian realm, 302.
Pediculus (illus.), 188.
 Pelagic fauna, 304.
 Pelican, brown (illus.), 125.
Peneus, adult and larva (illus.), 195.

- Pharynx, 71.
Phlegethontius carolina, larva of (illus.), 215.
Phrynosoma blainvillei (illus.), 131.
Phyllium (illus.), 210.
 Phyllopteryx (illus.), 212.
Physalia (illus.), 175.
 Physiology, 64.
Physoptora (illus.), 47.
 Pocket-gopher, nest of (illus.), 271.
 Pointer dog (illus.), 256.
Polistes, parasitized by *Stylops* (illus.), 192.
 Polygamy, 59.
 Polymorphism, 42.
 Polyps, 37.
Polystomella strigillata (illus.), 17.
 Porcupine-fish (illus.), 134.
 Post-embryonic development, 80.
 Pigeon horn-tail (illus.), 191.
 Pipe-fish (illus.), 212.
Planaria, alimentary canal of (illus.), 70.
 Plankton, 304.
 Plants, difference between animals and, 111.
Platophrys lunatus (illus.), 100.
 Play, instincts of, 247.
 Pluteus, 96.
 Præcocial, 140.
 Prawn, adult and larva (illus.), 195.
 Praying-horse (illus.), 127.
 Pressure, a condition of animal life, 109.
 Primitive form, 20.
 Primitive life, 21.
Prionus, larva of (illus.), 146.
 Processes, life, 21.
 Prometheus moth (illus.), 231.
Prophysema primordiale (illus.), 34.
 Protective resemblance, 201.
 Protoplasm, 3; chemical constitution of, 4; physical constitution of, 4.
 Protozoa, 1; colonial, 24; marine, 15.
Psalttriparus minimus, nest of (illus.), 270.
 Pseudopod, 5.
Pterophryne histrio in *Sargassum* (illus.), 208.
 Pupa, 93.
 Puss moth, larva of (illus.), 216.
 Quiescence, degeneration through, 193.
 Rabbit, embryonic stages of (illus.), 87.
 Radiolaria, 16.
 Radiolaria-ooze, 19.
Raja binoculata (illus.), 140.
 Realm, Arctic, 297; Australian, 303; Indo-African, 301; Lemurian, 302; Neotropical, 301; North Temperate, 299; of animal life, 297; Patagonian, 302; South American, 301.
 Realms, subordinate, 303.
 Reason, 251.
 Recognition marks, 22, 129, 223.
 Rectum, 68.
 Reflex action, 241.
Remora (illus.), 173.
Remora remora (illus.), 125.
 Reproduction, 9, 50; instincts of, 249.
 Reproductive cells, 28, 55.
 Resemblance, aggressive, 202; general protective, 202; protective, 201; special protective, 207; variable protective, 204.

- Respiration, 7.
 Resting spore, 28.
 Reticulum, 67.
Rhizocrinus loxotensis (illus.), 305.
 Rivalry, adaptations for, 135.
 Rookeries, fur-seal (illus.), 160.
 Rumen, 67.

Sacculina (illus.), 187.
Sacculina, adult and larva (illus.), 195.
Salamander, embryonic stages of (illus.), 87.
Saliva, 67.
Salmon leaping (illus.), 289.
Salmo viridens (illus.), 145.
Sarcoptes (illus.), 192.
Sauba, ant mimicked by *Membracidae* (illus.), 220.
Scale, red orange (illus.), 196.
Schilbeodes furiosus (illus.), 132.
Schistocerca (illus.), 280.
Scorpion (illus.), 127.
Scorpion-fish (illus.), 132.
Sea, a barrier to distribution, 288.
Sea, faunal areas of, 304.
Sea-anemone, 37; with algæ in body (illus.), 178.
Sea-cow (illus.), 277.
Sea-cucumber, alimentary canal of (illus.), 70.
Sea-squirt (illus.), 194.
Sea-urchin, metamorphosis of (illus.), 96.
Sea-urchins (illus.), 259.
Seal, fur (illus.), 136; pups killed by parasite (illus.), 186; rookeries (illus.), 169.
Selection, artificial, 120; natural, 117.
Self-defense, adaptations for, 128; instincts of, 245.
Sensation, 8.

Senses, special, 224; of the simplest animals, 225.
Sensorium, 241.
Serphus (illus.), 141.
Sex, 57; object of, 57; dimorphism, 58.
Shark-clinging fish (illus.), 125.
Sheep, bighorn (illus.), 167; Rocky Mountain (illus.), 167.
Sight, sense of, 237.
Simplest animals, life of, 1.
Siphonophora, 46.
Skate, egg case of California barn-door (illus.), 140; egg of (illus.), 79.
Skin of man, tactile papilla of (illus.), 227.
Smell, sense of, 229.
Smelling organs, 229.
Smelling pits of leaf-eating beetle (illus.), 230.
Social life, 149.
Sound-making, 235; organs, 235.
South American realm, 301.
Specialization, 66; of organs, 66.
Special senses, 224.
Species, altered by adaptation to new conditions, 276; debarred by barriers, 274; debarred by inability to maintain their ground, 275; definition of, 279; relation of, to habitat, 283.
Sperm cell, 35, 56.
Sphinx moth, larva of (illus.), 215.
Spicules, sponge, 33.
Spiders (illus.), 212; nest-making habits of, 259.
Sponges, 32.
Spongin, 36.
Spontaneous generation, 51.
Spore, 15, 52; resting, 28.
Sting-ray (illus.), 133.

- Structure, 63; differentiation of, 64.
 Struggle for existence, 116.
Stylops parasitizing *Polistes* (illus.), 192.
 Sub-species, definition of, 282.
 Surroundings, adaptations concerned with, 143.
 Swallow-tail butterfly, chrysalid of (illus.), 205.
 Sword-fish, metamorphosis of (illus.), 99.
 Symbiosis, 172, 175.
Syngamus trachealis (illus.), 60.
 Systematic zoölogy, 64.
- Tactile organs, 226.
 Tactile papilla of skin of man (illus.), 227.
 Tadpole, 94.
Tænia solium (illus.), 183.
 Tailor-bird, nest of (illus.), 263.
 Tape-worm (illus.), 183.
 Taste buds of calf (illus.), 229.
 Taste organs, 228.
 Taste, sense of, 228.
 Temperature a barrier to distribution, 290; a condition of animal life, 108.
 Tentacle, 37.
 Termite, 158, (illus.), 159.
 Terrifying appearances, 212.
Thalessa lunata (illus.), 191.
 Toad, egg of (illus.), 79; horned (illus.), 131; metamorphosis of, 94, (illus.), 95.
 Torpedo (illus.), 135.
 Tortoise, embryonic stages of (illus.), 87.
 Touch, sense of, 226.
 Trap-door spider nest (illus.), 261.
 Tree-hoppers mimicking leaf-cutting ant (illus.), 220.
- Tree-toad (illus.), 145.
Tremex columba (illus.), 191.
Trichechus latirostris (illus.), 277.
Trichina spiralis (illus.), 184.
 Tripoli, 19.
Trochilus rufus, nest of (illus.), 265, 266.
 Trout, rainbow, head of (illus.), 145.
 Two Ocean Pass (illus.), 287.
 Tunicate (illus.), 194.
 Turret-spider, nest of (illus.), 262.
Typhlichthys subterraneus (illus.), 282.
- Uncinaria*, killing fur-seal pups (illus.), 186.
Uria lomvia arra (illus.), 165.
Urolophus goodei (illus.), 133.
- Vacuole, 10; contractile, 10.
 Variety, definition of, 282.
Vedalia and *Icerya*, 121.
 Vertebrates, early stages in development of (illus.), 87; nest-making habits of, 264; parasitic, 193.
Vespa (illus.), 162; nest of (illus.), 163.
 Vestigial organs, 147.
 Viceroy butterfly mimicking Monarch butterfly (illus.), 219.
 Voice, 236.
 Volvocinæ, 24.
Volvox, 28.
Volvox globator (illus.), 29.
Volvox minor (illus.), 29.
Vorticella, 12.
Vorticella microtoma (illus.), 12.
- Walking-stick insect (illus.), 209.
 Warning colors, 212.
 Walrus, Atlantic (illus.), 298.

- Wasps, social, 161.
Water - beetle (illus.), 146; bug,
 giant (illus.), 141.
Whippoorwill (illus.), 203.
Woodpecker, Californian, feeding
 habit of (illus.), 128, 129.
Xiphias gladius, metamorphosis
 of (illus.), 99.
Yellow-jacket (illus.), 162.
Yolk, 80.
Young, adaptations for defense of,
 137; care of the, 250, 257; num-
 ber of, 61.
Zoea, 97.
Zoogeography, 272.
Zoology, systematic, 64.

THE END



Murres and nests (*Uria lomvia arva*). Walrus Island, Pribilof group.
Photograph by HARRY CHICHESTER.

TWENTIETH CENTURY TEXT-BOOKS

ANIMAL FORMS

A TEXT-BOOK OF ZOOLOGY

BY

DAVID STARR JORDAN, Ph. D.

PRESIDENT OF LELAND STANFORD JUNIOR UNIVERSITY

AND

HAROLD HEATH, Ph. D.

ASSISTANT PROFESSOR OF ZOOLOGY, LELAND STANFORD JUNIOR
UNIVERSITY



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P R E F A C E

THE present volume is designed to meet the needs of the beginning student of zoology. Accordingly, technical and scientific names have been avoided as far as possible, and those used are fully explained in the text or elsewhere. The opening chapters deal with the characteristics of living things, and, in contrasting animals and plants, attempt to bring into relief the distinguishing marks of all animals. Then follows a discussion of the cell and protoplasm, preparing the way for the examination of a series of animals representative of each of the great groups, from the simplest to the most complex. These are considered from the view-point of structure; but considerable attention is also paid to the functions of their parts, to their habits and life-history, so that while the representatives examined are, for the sake of simplicity, relatively few in number, they are, it is believed, thoroughly typical. Hence, with a knowledge of the facts presented, the student should have a broad view of the animal kingdom, and a foundation on which to base future study and observation. It is perhaps unnecessary to add that from the study of books alone no one can really make such knowledge his own. A personal acquaintance with even a few animals in their native haunts, and an understanding of the structure and the function of their

v

parts gained from dissection and experiment, is essential to a full comprehension of what the student learns from text-book and teacher.

The greater number of illustrations are new, and have been drawn or photographed from living or preserved material. When not otherwise accredited, the drawings have been made by Miss Mary H. Wellman and J. Carter Beard, to whom the authors extend their sincere thanks. Our obligations are also due to Mr. Walter K. Fisher, who has made the drawings of the vertebrate dissections; to Messrs. A. L. Melander and C. T. Brues, of Chicago, Ill.; Mr. Wm. H. Fisher, of Baltimore, Md.; Rev. H. K. Job, of Kent, Conn.; Mr. Wm. Graham, of Pasadena, Cal.; and Dr. R. W. Shufeldt, of New York city, for numerous photographs.

DAVID STARR JORDAN,
HAROLD HEATH.

CONTENTS

CHAPTER	PAGE
I.—INTRODUCTION	1
II.—THE CELL AND PROTOPLASM	7
III.—THE PROTOZOA	11
IV.—THE SPONGES	19
V.—THE CœLENTERATES	29
VI.—THE WORMS	44
VII.—ANIMALS OF UNCERTAIN RELATIONSHIPS	66
VIII.—MOLLUSKS	72
IX.—ARTHROPODS. CLASS CRUSTACEA	93
X.—ARTHROPODS. CLASS INSECTS	114
XI.—ARTHROPODS. CLASS ARACHNIDA	133
XII.—ECHINODERMS	140
XIII.—THE CHORDATES	151
XIV.—THE FISHES	154
XV.—THE AMPHIBIANS	174
XVI.—THE REPTILES	184
XVII.—THE BIRDS	201
XVIII.—THE MAMMALS	225

vii

ANIMAL FORMS

CHAPTER I

INTRODUCTION

1. **Divisions of the subject.**—Biology is the science which treats of living things in all their relations. It is subdivided into Zoology, the science which deals with animals, and Botany, which is concerned with plants. The field covered by each of these branches is very extensive. Within the scope of zoology are included all subjects bearing on the form and structure of animals, on their development, and on their activities, including the consideration of their habits and the wider problems of their distribution and their relations to one another.

These various subjects are often conveniently grouped under three heads: Morphology, which treats of the form and structure or the anatomy of organisms; Physiology, which considers their activities; and Ecology, which includes their relations one to another and to their surroundings. All the phases of plant or animal existence may be considered under one or another of these three divisions.

2. **The difference between animals and plants.**—Generally speaking, we have little difficulty in seeing that the objects about us are either living or lifeless; but the boundary line between the two great divisions of living things, the animals and plants, can not always be so clearly drawn. This is especially true of the simpler forms of life which frequently combine both animal and plant characteristics; but in the

greater number of more highly developed species the line of separation is clearly marked. It is very easy, for example, to distinguish the oak-tree or the rose from a horse or a butterfly, and, as we shall see, the differences are not based merely on outward appearance.

In the oak-tree, for example, the roots reaching down into the earth, with the branches and leaves spreading out into the air and sunlight, are admirably fitted for taking up the food, which consists of very simple materials, less complex than those forming the diet of an animal. This permits a continuous existence in one place, and accordingly we note the entire absence of locomotion and the organs controlling it, which form so conspicuous a part of the body of an animal. Also in the production of flowers and seeds, and in the growth of the seed into the tree, we detect many characteristics peculiar to plants.

3. Characteristics of an animal.—On the other hand, the squirrel, for example, or any other animal, is unable to subsist on water, air, and elements from the soil. These creatures demand the highly diversified materials found in the bodies of plants and of animals. Such being the case, they do not remain anchored to one spot (except in a relatively few cases), but are compelled to lead an active existence. The power of voluntary movement, or movement in response to internal impulse, is thus the first and one of the most striking peculiarities of animals.

In the second place, the food of plants enters the body in a soluble condition and is readily transferred to the organs requiring it. While in the animals, the nutritive materials pass into the body in an insoluble state and demand a varied preliminary treatment, usually within a special digestive tube, before they are fit to be absorbed. In the squirrel, by way of illustration, the food is first ground to a pulp by the action of the teeth, and, moistened with saliva, is swallowed and passed into the stomach, where it is subjected to the solvent action of the gastric

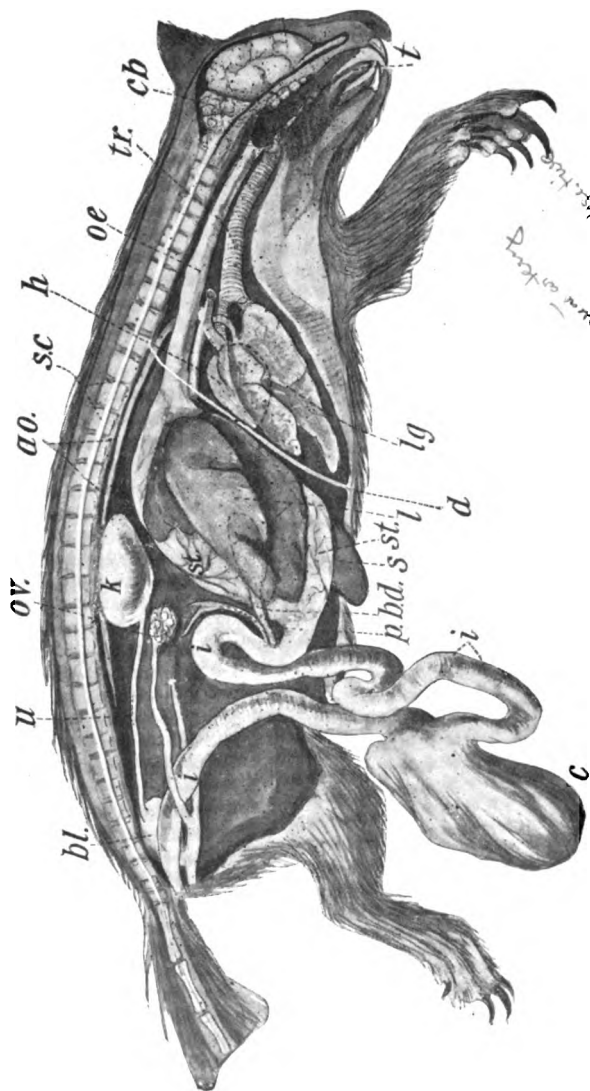


FIG. 1.—Dissection of ground squirrel (*Spermophilus*) with viscera slightly displaced. ae., aorta; b.d., bile duct; bl., bladder; c, blind pouch of intestine or caecum; cb., brain; d., diaphragm; h., heart; i., intestine; k., kidney; l., liver; lg., lung; oe., oesophagus; ov., ovary; p., pancreas; s., spleen; s.c., spinal cord; st., stomach; t., tongue; tr., trachea; u., ureter.

juice. From the stomach it is made to enter the intestine, and is further acted upon by fluids from the liver, the pancreas, and the glands of the intestines themselves. Thus treated it becomes changed from an insoluble state into a fluid which readily penetrates the coats of the digestive tract.

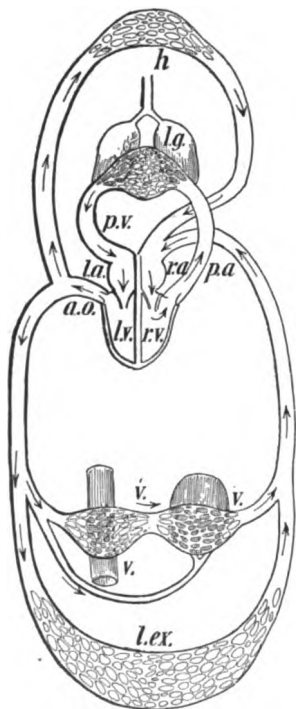


FIG. 2.—Diagram of heart and blood-vessels of the squirrel or other mammal. *a.o.*, aorta; *h*, vessels of head; *l.a.*, left auricle; *l.ex.*, vessels of lower extremities; *lg.*, lung; *l.v.*, left ventricle; *p.a.*, pulmonary artery; *p.v.*, pulmonary vein; *r.a.*, right auricle; *r.v.*, right ventricle; *v.*, vessels of viscera. Arteries are represented by heavy walls.

Many of the organs of the body are placed at a considerable distance from the food as it comes through the coats of the stomach and intestine. In order to supply them with the necessary nourishment a distributing apparatus is required. This is the office performed by the circulatory system, for as rapidly as the food penetrates the walls of the digestive tract it enters the blood, and by the beating of the heart is driven to all parts of the body, which are thus continually kept in a state of repair. The blood serves also to remove waste substances from the various structures or organs of the animal body and to transfer them to the kidneys, skin, or lungs, which effect their removal from the body.

4. Muscular and nervous systems.—Owing to the fact that animals, as a rule, are compelled to move about in search of food, we find two highly developed systems, the muscular and nervous, which are absent

in the plants. The first of these, constituting what is usually known as the lean meat, is a relatively complex system of organs, differing widely according to the work performed. In the higher animals—the squirrel, for example—there are not less than five hundred muscles, which are under the control of the nervous system.

The nervous system consists of the brain and spinal cord, which in the squirrel are concealed and protected



FIG. 3.—Skeleton of squirrel, showing its relation to the body.

within the skull and back-bone. From them many nerves pass outward to the muscles, and as many pass inward from the eye, ear, nose, tongue, or skin. By the action of these sense-organs the animal determines the nature of its surroundings, detects its food, recognizes the presence of its enemies, and is thus able to direct its movements to the greatest advantage.

5. Multiplication of animals.—The organs thus far considered serve to perpetuate the animal as an individual; but some provision must also be made for the continuance of the race. In the economy of nature each animal before

its death should leave offspring to take the place of the parent when it falls from the ranks. This is effected in various ways. In some of the simpler animals the body may divide into two equal parts, each of which becomes a complete individual. In other cases the animal detaches a relatively small portion of its body, much as a gardener cuts a slip from a plant, and this likewise develops into a new organism. In the greater number of animals, very clearly illustrated by the birds, eggs are produced which under favorable conditions develop into an organism resembling the parents.

6. **Summary.**—Animals are thus seen to lead active, busy lives, collecting food, avoiding enemies, and producing and caring for their young. While the activities of all animals are directed to their own preservation and to the multiplication of their kind, these processes are carried on in the most diverse ways. The manner in which an organ or an organism is made, and the method by which it does its work, are mutually dependent one on the other. As there is an enormous number of species of animals, each differently constructed, there is, accordingly, a very great variety of habits. As we shall see, the lower forms are remarkably simple in their construction, and their mode of existence is correspondingly simple. In the higher types a much greater complexity exists, and their activities are more varied and are characterized by a high degree of elaboration. In every case, the animal, whether high or low, is fitted for some particular haunt, where it may perform its work in its own special way and may lead a successful life of its own characteristic type.

CHAPTER II

THE CELL AND PROTOPLASM

7. **Cells.**—If we examine very carefully the different parts of a squirrel under the high powers of the microscope we find that they are composed of a multitude of small structures which bear the same relations to the various organs that bricks or stones do to a wall; and if the investigation were continued it would be found that every organism is composed of one or more of these lesser elements which bear the name of *cells*. In size they vary exceedingly, and their shapes are most diverse, but, despite these differences, it will be seen that all exhibit a certain general resemblance one to the other.

8. **Shape of cells.**—In many of the simpler organisms the component cells are jelly-like masses of a more or less spherical form, but as we ascend the scale of life the condition of affairs becomes much more complex. In the squirrel, for example, we have already noted the presence of various organs for carrying on different functions, such as those of digestion, circulation, and respiration; and, further, the cells composing these various parts have been modified in accordance with the duties they have to perform. In the muscles the cells are long and slender (Fig. 4, D); those forming the nerves and conveying sensations to and from all parts of the body, like an extensive telegraph system, are excessively delicate and thread-like; in the skin, and lining many cavities of the body, where the cells are united into extensive sheets, they range in shape from high and columnar to flat and scale-like forms (Fig. 4, E, F, G).

The cells of the blood present another type (Fig. 4, B); and so we might pass in review other parts of the body, and continue our studies with other groups of animals, always finding new forms dependent upon the part they play in the organism.

9. **Size of cells.**—Also in the matter of size the greatest variations exist. Some of the smallest cells measure less than one micromillimeter ($\frac{1}{25000}$ of an inch) in diameter. Over five hundred million such bodies could be readily stowed away into a hollow sphere the size of the letter beginning this sentence. In a drop of human blood of the same size, between four and five million blood-cells or corpuscles float. And from this extreme all sizes exist up to those with a diameter of 2.5 or 5 c.m. (one or two inches), as in the case of the hen's or ostrich's egg. On the average a cell will measure between .025 to .031 m.m. ($\frac{1}{4000}$ and $\frac{1}{3125}$ of an inch) in diameter, a speck probably invisible to the unaided eye. While the size and external appearance of a cell are seen to be most variable, the internal structures are found to show a striking resemblance throughout. All are constructed upon essentially the same plan. Differences in form and size are superficial, and in passing to a more careful study of one cell we gain a knowledge of the important features of all.

10. **A typical cell.**—Some cell, for example that of the liver (Fig. 4, A), may be chosen as a good representative of a typical cell. To the naked eye it is barely visible as a minute speck; but under the microscope the appearance is that of so much white of egg, an almost transparent jelly-like mass bearing upon its outer surface a thin structureless membrane that serves to preserve its general shape and also to protect the delicate cell material within. The comparison of the latter substance to egg albumen can be carried no further than the simple physical appearance, for albumen belongs to that great class of substances which are said to be non-living or dead, while the cell material

or *protoplasm*, as it is termed, is a living substance. We know of no case where life exists apart from protoplasm, and for this reason the latter is frequently termed the physical basis of life.

In addition to the features already described, the protoplasm of every perfect cell is modified upon the interior to

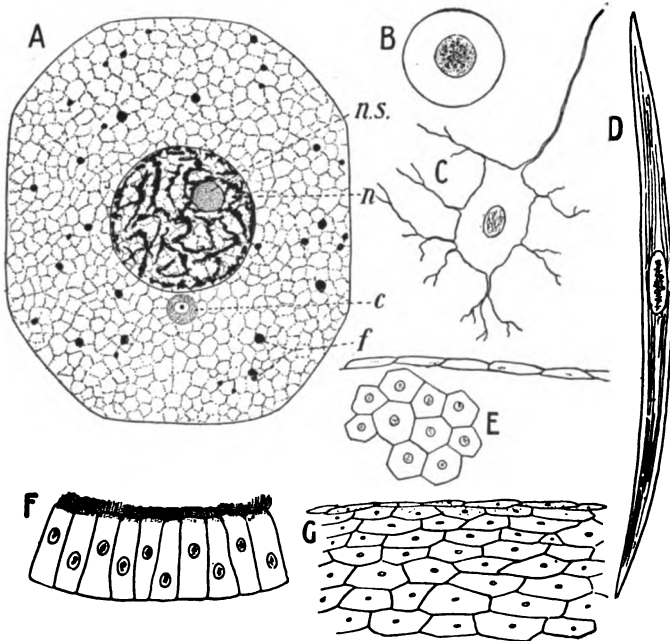


FIG. 4.—Different types of cells composing the body of the squirrel or other highly developed animal. A, liver-cell; *f*, food materials; *n*, nucleus. B, blood-cell. C, nerve-cell with small part of its fiber. D, muscle fiber. E, cells lining the body cavity. F, lining of the windpipe. G, section through the skin. Highly magnified.

form a well-defined spherical mass known as the *nucleus*. Other structures are known to occur in the typical cell. Experiment shows that the nucleus and cell protoplasm are absolutely indispensable, whatever their size and shape, and

therefore we are at present justified in defining the cell as a small mass of protoplasm enclosing a nucleus.

11. Structure of protoplasm.—When seen under a lens of moderate power protoplasm gives no indication of any definite structure, and even with the highest magnification it presents appearances which are not clearly understood. According to the commonly accepted view, it consists of two portions, one, the firmer, forming an excessively delicate meshwork (Fig. 4, A) enclosing in its cavities the second more fluid part. Therefore, when highly magnified, the appearance would be essentially like a sponge fully saturated with water; but it should be remembered that in the protoplasm the sponge work, and possibly the fluid part, is living, and that both are transparent.

There are reasons for thinking that the structure and the composition of protoplasm may change somewhat under certain circumstances. It certainly is not everywhere alike, for that of one animal must differ from that of another, and different parts, such as the liver and brain, of the same form must be unlike. These differences, however, are minor when compared to the resemblances, for, as we shall see, this living substance, wherever it exists, carries on the processes of waste, repair, growth, sensation, contraction, and the reproduction of its kind.

CHAPTER III

THE PROTOZOA

12. Single-celled and many-celled animals.—In almost every portion of the globe there are multitudes of animals whose body consists of but a single cell; while those forms more familiar to us, and usually of comparatively large size and higher development, such as sponges, insects, fishes, birds, and man himself, are composed of a multitude of cells. For this reason the animal kingdom has been divided into two great subdivisions, the Protozoa including all unicellular forms and the Metazoa embracing those of many cells.

13. Single-celled animals.—The division of the Protozoa comprises a host of animals, usually of microscopic size, inhabiting fresh or salt water or damp localities on land in nearly every portion of the globe. The greater number wage their little, though fierce, wars on one another without attracting much attention; others, in the sharp struggle, have been compelled to live upon or within the bodies of other animals, and many have become notorious because of the diseases they produce under such circumstances. A few are in large measure responsible for the phosphorescence of the sea; and still others have long been favorite objects of study because of their marvelous beauty. Adapted for living under diverse conditions, the bodily form differs greatly, and yet all conform to three or four principal types, of which we may gain a good idea from the study of a few representative forms.

14. **The Amœba.**—Among the simplest one-celled animals living in the ooze at the bottom of nearly every fresh-water stream or pond is the *Amœba* (Fig. 5, A), whose body is barely visible to the unaided eye. Under the microscope

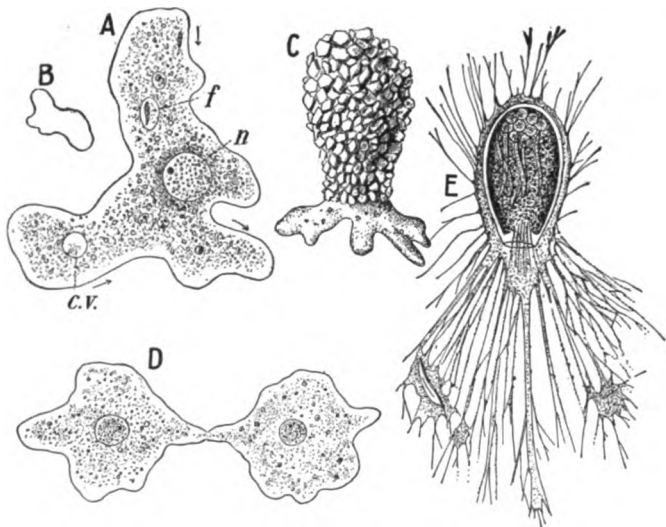


FIG. 5.—A, the *Amœba*, highly magnified, showing *c. v.*, pulsating vacuole; *f*, food particle; *n*, nucleus. The arrows show the direction of movement. B, shape of same individual 30 seconds later. C, an amœba-like animal (*Difflugia*) partially enclosed in a shell. D, an *Amœba* in the process of division. E, *Gromia*, another shelled protozoan (after SCHULZE).

it is seen to consist of an irregular, jelly-like mass of protoplasm totally destitute of a cell wall. Unlike those animals with which we are familiar, the body constantly changes its shape. A rounded bud-like projection will be seen to appear on one side of the body and the protoplasm of adjacent regions flows into it, thereby increasing its extent. Similar projections at the opposite end of the cell are withdrawn, and their substance may flow into the newly formed lobe, which gradually swells in size and pushes forward. Thus, by constantly advancing the front part of the body and

retracting the hinder portion, the cell glides or flows along from place to place.

Upon meeting with any of the smaller organisms upon which it lives, projections from the body are put out which gradually flow around the prey and it becomes pressed into the interior of the cell. The process is not unlike pushing a grain of sand into a bit of jelly. There is no mouth. Any point on the surface serves for the reception of food. Oxygen gas also is taken into the body all over the surface, and wastes and indigestible material are cast out at any point. Nothing exists in these simple forms comparable to the complex systems of organs that carry on these processes in the squirrel.

The bodily size of animals is limited, and to this general rule the *Amœba* is no exception, for upon gaining a certain size, the nucleus divides into two exactly similar portions, and very soon afterward the rest of the body separates into two independent masses of equal size (Fig. 5, D), each of which, when entirely free, contains a nucleus. In this way two daughter amœbæ are formed possessing exactly the characters of the parent save that they are of smaller size; but it is usually not long before they reach their limit of growth, when division occurs again, and so on, generation after generation.

It not infrequently happens, however, that the pond or stream, in which the *Amœba* and other Protozoa live, dries up for a portion of the year. In such an event the body assumes a spherical shape, develops a firm, horn-like membrane about itself, and thus *encysted* it withstands the summer's heat and dryness and may be transported by the wind, or otherwise, over great distances. When the conditions again become favorable the wall ruptures and the *Amœba* emerges to repeat its life processes.

15. Some relatives of the *Amœba*.—All amœba-like forms, to the number of perhaps a thousand species, possess this same method of locomotion, but many present some inter-

esting additional characters. For example, the form represented in Fig. 5, C, constructs a sac-like skeleton of tiny pebbles cemented together, into which it may withdraw for protection. Others construct similar envelopes of lime or flint, and still others, as they continue to grow, build on additional chambers, giving rise to a great variety of forms often of wonderful beauty. In the tropics, particularly, some of the shelled Protozoa are so abundant that they may impart a whitish tinge to the water, and in some places their empty shells on falling to the bottom form immense deposits. The chalk cliffs of England are in large measure made up of such shells.

16. **The Infusoria.**—A little over two hundred years ago it was discovered that wherever water remained stagnant it became favorable for the rapid multiplication of a large number of species of Protozoa which live in such situations. These are known as Infusoria, and, like the preceding species, are usually of microscopic size and of the most varied shapes. The first striking feature of their organization is the presence of a delicate though relatively firm external cell membrane known as the *cuticle*, which preserves a definite shape to the body. Such a method of locomotion as exists in the preceding group is consequently an impossibility, but other and more highly developed structures perform the office. These latter organs are of two types, and their general characteristics may be readily understood from an examination of a few species living in the same localities as the *Amœba*.

17. **The Euglena.**—The first type exists in the common fresh-water organism known as *Euglena*, represented in Fig. 6, A. Here the spindle-shaped body is surrounded by a delicate cuticle perforated at one point, where a funnel-shaped depression, the gullet, leads into the soft protoplasmic interior. From the base of this depression the protoplasm is drawn out in the form of a delicate whip-like process known as the *flagellum*. This structure, always

permanent in form, constantly beats backward and forward with great rapidity in a general direction represented in the diagram (Fig. 6, c). The movement from *a* to *b* is much more rapid than the reverse, from *b* to *a*, which results, like the action of the human arm in swimming, in driving the organism forward. Not only does the flagellum serve the purpose of locomotion, but it also produces currents in the water which may serve to bear minute organisms down into the gullet, whence they readily pass into the soft pro-

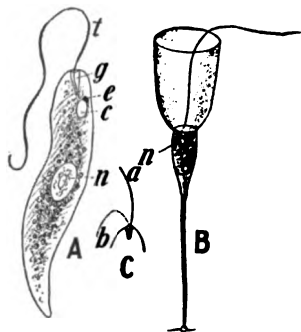


FIG. 6. — Flagellate Infusoria. A, *Euglena viridis*; *c*, pulsating vacuole; *e*, eye-spot; *g*, gullet; *n*, nucleus; *t*, flagellum. B, *Codonogaster*, with collar surrounding the flagellum. C, diagram illustrating the action of the flagellum. All figures greatly enlarged.

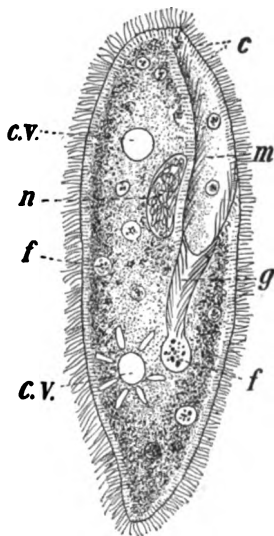


FIG. 7. — *Paramacium aurelia*, a ciliate infusorian. *c*, cilia; *c.v.*, pulsating vacuoles; *f*, food particles; *g*, gullet; *m*, buccal groove; *n*, nucleus.

toplasm of the body, there to undergo the processes of digestion and assimilation. In some forms the protoplasm in the region of the flagellum is drawn out in the form of a collar (Fig. 6, B), whose vibratory motion also aids in conveying and guiding food into the body.

18. **The Slipper Animalcule.**—The second type of locomotor organ may be understood from a study of the

Slipper Animalcule (*Paramœcium*, Fig. 7), abundant in stagnant water. In this form the cuticle surrounding the somewhat cylindrical body is perforated by a great number of minute openings through which the internal protoplasm projects in the form of delicate threads. Each process, termed a *cilium*, works on the same principle as the flagellum, but it beats with an almost perfect rhythm and in unison with its fellows, drives the animal hither and thither with considerable rapidity.

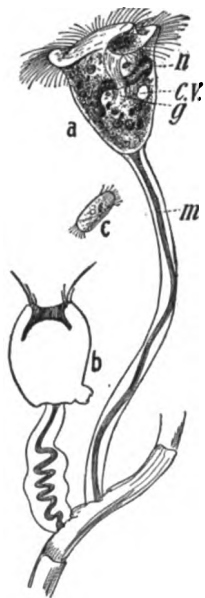


FIG. 8.—*Vorticella*, an attached ciliate infusorian, highly magnified. a, fully extended individual; c.v., pulsating vacuole; g, gullet; n, nucleus. b, contracted specimen. c, small free-swimming individual, which unites with a stationary individual (one partly united is shown in specimen b).

On one side of the body is a furrow which deepens as it runs backward and finally passes into the gullet (*g*), which leads into the interior of the body. Throughout the entire extent it is lined with cilia which create strong currents in the surrounding water and in this way conduct food down the gullet into the body. Embedded in the outer surface of the body, in among the cilia, are also a number of very minute sacks, each containing a coiled thread which may be discharged against the body of any intruder, so that this form is supplied with actual organs of defense. Two *pulsating vacuoles* (*c.v.*) or simple kidneys are also present, consisting of a central reservoir into which a number of radiating canals extend.

19. The Bell Animalcule and other species.—The Bell Animalcule (*Vorticella*, Fig. 8) is often found in the same situations as the Slipper Animalcule, which in certain respects it resembles. It is generally attached by a slender stalk, and where many

are growing together they appear like a delicate growth of mold upon the water weed. The stalk is peculiar in being traversed by a muscle fiber arranged in a loose spiral, which upon any unusual disturbance contracts together with the body into the form shown in Fig. 8, *b*.

These few examples serve to show the general plan of organization and the method of locomotion of the Infusoria; but, as upward of a thousand species exist, with widely differing habits, many interesting modifications are present. Some have been driven in past time to adopt a parasitic mode of life within the bodies of other animals. At present they are devoid of locomotor organs, and as they absorb nutritive fluids through the surface of the body all traces of a mouth are also absent. The reproductive processes also are peculiar, but they do not concern us now.

20. Characteristics common to the Protozoa.—We have now studied the principal structures which serve in locomotion among these simple one-celled forms, also the means by which they catch their food, and we shall now glance at the internal processes, which are much the same in all.

After the food has been taken into the cell, it is probably acted upon by some digestive fluid, for it soon assumes a granular appearance and finally undergoes complete solution. In every case the oxygen is absorbed through the general surface of the body, and uniting with the living substance, as in the squirrel, liberates the energy necessary for the performance of the animal's life work. The wastes thus produced in a large number of forms simply filter out from the body without the agency of anything comparable to a kidney, but in several species they are borne to a definite spot, the pulsating vacuole (Figs. 5, 7, 8, *c.v.*), where they gradually accumulate into a drop about the size of the nucleus. The wall between it and the exterior now gives way and the excretions are passed out. In active individuals this process may be repeated two or three times a minute, but it is usually of less frequent occurrence.

The loss in bodily waste is continually made good by the manufacture of the food into protoplasm, and if the income be greater than the outgo growth ensues. But, as in all other forms, growth is limited, and ultimately the cell is destined to divide, resulting in two new individuals. This process may be repeated many times, but not indefinitely, for sooner or later various members of the same species unite in pairs temporarily or permanently, exchange nuclear material, and separate again with apparently renewed energy and the ability to divide for many generations.

21. **Simple and complex animals.**—It is important to note that these same processes of waste, repair, growth, feeling, motion, and multiplication are the same as those of the squirrel, and, furthermore, are common to all living creatures, so that the difference between animals is not in their activities, but in their bodily mechanisms; and according to the perfection of this, the animal is high or low in the scale. Comparing, for example, the *Amæba* and Slipper Animalcule, which are relatively low and high Protozoa, we find in the former that any part of the body serves in locomotion and in the capture of food, while in the latter these same functions are performed by definite structures, the cilia and gullet. Now it is well known that a workman is able to make better watch-springs, when this is his sole duty, than another who must make all parts of the watch; and likewise where a definite task is performed by a definite structure, it is more efficiently done than where any and every part of the body must carry it on. So the *Amæba*, in which definite tasks are performed by any part of the body indifferently, is less perfect and thus lower than the *Paramæcium*, where these functions are performed by special organs. As we ascend the scale of life we find this division of labor among special parts of the body more complete, the organs and therefore the animal more complete, and better fitted to carry on the work of its life.

CHAPTER IV

THE SPONGES

22. **Their relation to the Protozoa.**—While the greater number of one-celled forms are not united with their fellows, there are several species where the reverse is true. In Fig. 9, for example, a fresh-water form known as *Pandorina* is represented, consisting of sixteen cells embedded in a spherical, jelly-like substance, each one of which is precisely like its companions in form and activity. The aggregation may be looked upon as a colony of sixteen Protozoa united together to derive the benefit of increased locomotion and a larger amount of food in consequence. As a result of such a union they have not lost their independence, for if one be separated from the main company it continues to exist.

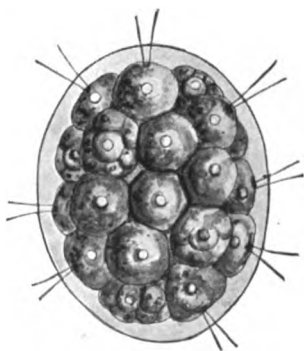


FIG. 9.—*Pandorina* (from Nature).
Highly magnified.

From such a simple colonial type we may pass through a series of several more complex forms which reach their highest development in the beautiful organism, *Volvox* (Fig. 10). In this form the individual members, to the number of many thousand, are arranged in the shape of a hollow sphere. The united efforts of the greater number, which bear on their outer surfaces two flagella, drive the colony with the rolling movement

from place to place. As just indicated, some individuals lack the flagella, and their subsequent careers show them to be of a peculiar type. Sooner or later each undergoes

a series of divisions forming a little globe of cells, which migrates into the interior of the parent sphere and develops into a new colony. Within a short time the walls of the parent break, liberating the imprisoned young, which continue the existence of the species while the parent organism soon decays.

Under certain circumstances, instead of developing colonies by such a method, some of the cells may store up food matters and become eggs, while others, known as sperm-cells, develop a flagellum, and separating from the colony swim actively in the surrounding water, where each finally unites with an egg. This union, like that of the two individuals in *Vorticella* (Fig. 8, b, c), results in the power of division, and the egg enters upon its development, dividing again and again. The cells so produced remain together, form a sphere, and finally develop

a *Volvox* colony.

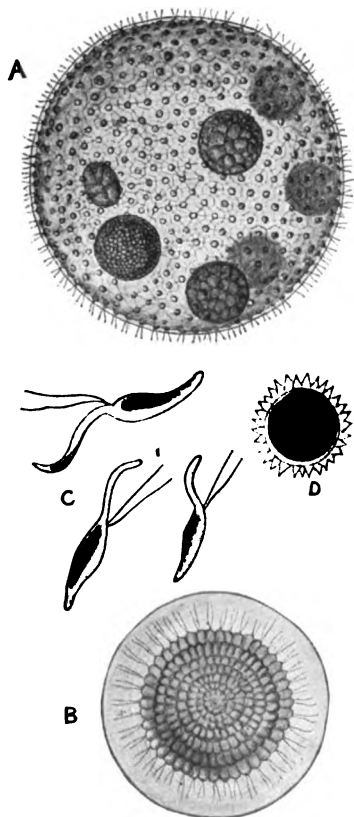


FIG. 10.—A, *Volvox minor*, entire colony (from Nature). B, C, and D, reproductive cells of *Volvox globator*. All highly magnified.

In such associations as *Volvox* an important step has been taken beyond that of *Pandorina*, for there is a division of the labors of the colony among its various members, some acting as locomotor cells while others are germ-cells. These are now so dependent one upon the other that they are unable to exist after separation from the main company, just as a part of the squirrel is incapable of leading an independent existence. A higher type of organism has thus arisen intermediate between the simple one-celled animals and those of many cells, especially the sponges—a relation which is more readily recognized after an examination of the latter.

23. Development of the sponge.—Like all many-celled animals, the sponge *begins* its life, however, as a single cell—the egg—which is in this case barely visible to the sharp unaided eye. Fertilized by its union with a sperm cell, development commences, and the first apparent indication of the process will be the division of the cell into halves (Fig. 11, A, B). Each half redivides into four, these again into eight cells, and this process is repeated, giving the young sponge the general form of *Pandorina*. The divisions of the cells still continue and result in the formation of a hollow globe of cells (called the *blastula*, Fig. 11, E, F) similar to *Volvox*, and at this point the young larva leaves the parent.

The next transformation consists in a pushing in of one side of the sphere, just as one might press in the side of a hollow rubber ball. The depression gradually deepens, and finally results in the formation of a two-layered sac known as the *gastrula* (Fig. 11, G). At this stage of its existence the sponge settles down for life in some suitable spot, by applying the opening of its sac-like body to some foreign object. In assuming the final form a new mouth breaks through what was once the bottom of the sac, canals perforate the body wall, a skeleton is developed, and the characteristic features of the adult are thus attained.

24. **Distribution.**—The sponges are aquatic animals, and, with the exception of one family consisting of relatively few species, all are inhabitants of the sea in every part of

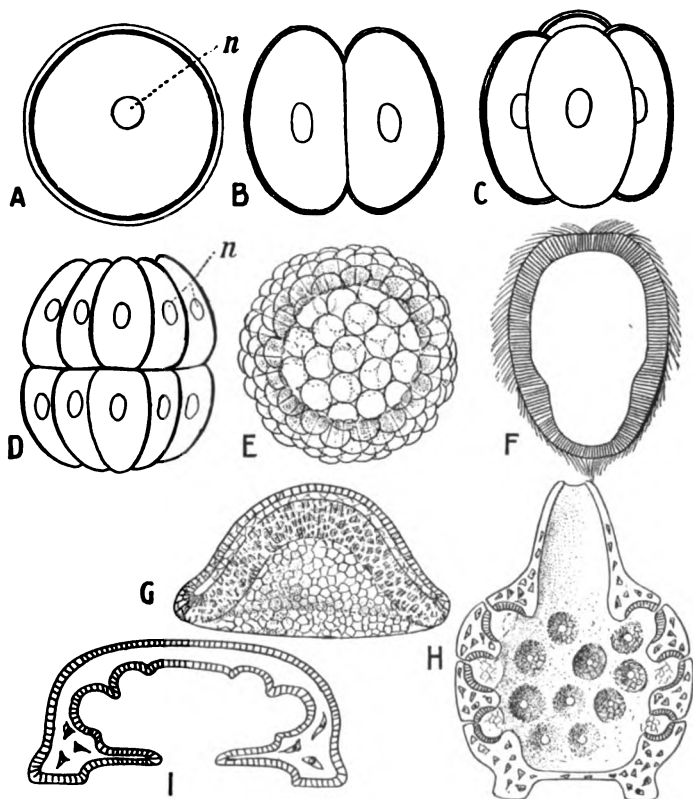


FIG. 11.—Diagrams illustrating the development of a sponge. A, egg-cell; *n*, nucleus. B, C, D, 2-, 4-, and 16-cell stages. E, *blastula*. F, section through somewhat older larva. G, *gastrula*. H, young sponge. I, section through somewhat younger larva than H.

the globe. The larger number occupy positions along the shore, becoming especially abundant in the tropics; but other species occur at greater depths, several species living

between three and four miles from the surface. Unlike the majority of animals, all members of this group are securely fastened to some foreign object, such as rocks, the supports of wharves, or with one extremity embedded in the sand. As we have seen, the young enjoy a free-swimming existence and are swept far and wide by means of tidal currents, but sooner or later these migrations are terminated in some suitable locality, where the sponge passes the remainder of its existence. During this time some species may never exceed the size of a mustard-seed, while others attain a diameter of three feet, or even more. Sponges also vary exceedingly in shape, some having the form of thin encrusting sheets, others being globular, tubular, cuplike, or highly branched (Fig. 12).

25. The influence of their surroundings.—In by far the larger number of cases an animal possesses the bodily form of the parent. External agencies may modify this to some extent, but usually only to a limited degree. A squirrel, for example, resembling its parent, may grow to a relatively large or stunted size according to the food supply, and it may become strong or weak according to the amount of exercise, and various other changes may result owing to outside causes; but as a result of these influences the animal is rarely so modified that one is unable to distinguish the species. Many of the sponges, however, are exceptions to this general rule. If, for example, some of the young of a certain parent develop in quiet water or in an unfavorable locality, they will usually be low, flat, and unbranched; while the others, growing in swiftly running waterways, develop into tall, comparatively delicate and highly branched individuals. Under such circumstances not only does the external form become modified, but the internal organization may undergo profound change. The entire organism is plastic and readily molded by the influence of its surroundings, and the consequent lack of definite characters often renders it impossible

to assign such forms to a definite position among the sponges.

26. Structure of a simple sponge.—In the simpler sponges the body is usually vase-shaped (Fig. 13), with the base fastened to some foreign object, while at an opposite end an opening leads into a comparatively large internal cavity. This latter space is also put in communication with the exterior by a multitude of minute pores which penetrate the body wall. In

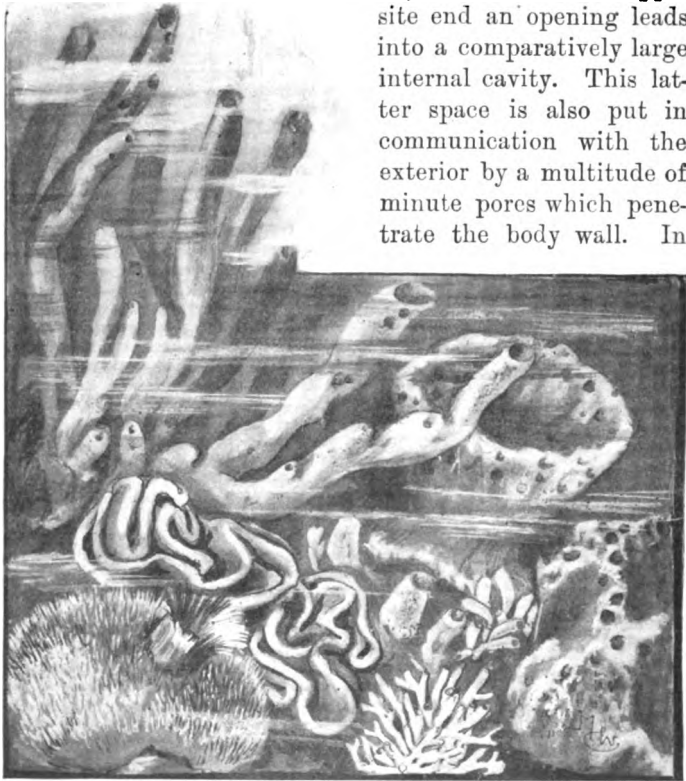


FIG. 12.—Various forms of sponges, natural size. (From Nature.)

the living condition currents of water continually pass through these smaller canals, and out of the large terminal opening, thus bringing within reach of the body minute

floating organisms or organic remains which serve as food. The mechanism by which this process is effected, and the various other structures of the body, are in large part invisible from the exterior, requiring the study of thin sections of the sponge to make them clearly understood.

Under the microscope such a section shows the body of a sponge to consist of an immense number of variously formed cells constituting three distinct layers (Fig. 14). Not only do these layers consist of different kinds of cells, but the duties performed by each are different. For example, a glance at Fig. 14 will show that in the inner layer certain columnar cells exist, provided with a flagellum and encircling collar, the appearance being strikingly like certain of the Protozoa (Fig. 6, B). During life their whip-like processes, lashing backward and forward in perfect unison, produce currents of water which continually pass through the body. The food thus entering the animal is taken up by the cells of the inner layer as it passes by. The supply, however, is usually more than sufficient to meet the demands of this layer, and the excess is passed on to the middle and outer layers. The exact method by which this occurs is still a matter of doubt, but there seems to be little question but that each cell of the body receives its food in a practically unmodified condition, requiring that it digest as well as assimilate. The oxygen necessary to this latter process

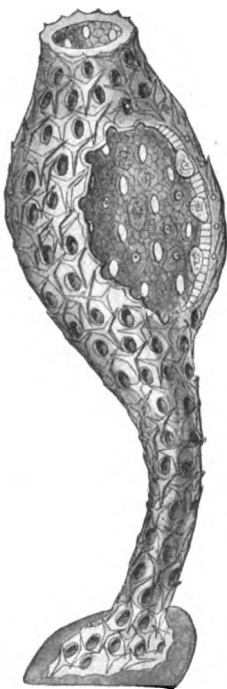


FIG. 13.—One of the simplest sponges (*Calcolynthus primigenius* (after HAECKEL). A portion of the wall has been removed to show the inside.

is absorbed by all parts of the body in contact with the water.

27. Skeleton of sponges.—When it is remembered that the protoplasm composing the cells of the sponge has about

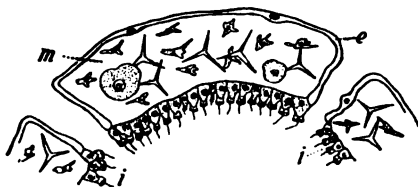


FIG. 14.—Portion of wall of sponge, showing three layers. *e*, outer layer; *i*, inner layer, consisting of collared cells; *m*, middle layer, consisting of irregular cells, among which are the radiate spicules and egg-cells.

the same consistence as the white of egg, it will be readily understood why the greater number of sponges possess a skeleton. Without such a support the larger globular or branched forms could not exist, and even in the

smaller members there would be danger of a collapse of the body walls and consequent stoppage of the food supply, owing to the closure of the pores. So in all but a very few thin or flat forms a skeleton appears in the young sponge

almost before growth has fairly begun, and this increases with the body in size and complexity. It is formed by the activity of the cells of the middle layer, and may be composed either of a lime compound resembling marble, or of flint, or of a

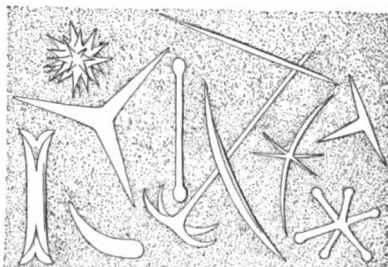


FIG. 15.—Different types of sponge spicules.

horn-like substance resembling silk, or these may exist in combination in certain species. When consisting of either of the first-named substances it is never formed in one continuous piece, but of a vast multitude of variously shaped crystal-like bodies termed spicules (Fig. 15). These occur everywhere throughout the body, firmly bound together

by means of cells, or so interlocked that they form a rigid support to which the fleshy substance is bound and through which the numerous canals penetrate.

In a relatively few species only does the skeleton consist of horn, though there are many in which horn and flint exist together. In the former event, if the skeleton be elastic and of sufficient size, it becomes valuable to others than the naturalist, for the familiar sponges of commerce are the horny skeletons of forms usually taken in the West Indies or in the Mediterranean Sea. In these localities the animals are pulled off by divers, or with hooks, and are then spread out in shallow water where the protoplasmic substance rapidly decays. The remaining skeleton, thoroughly washed and dried, is ready for the markets of the civilized world.

Examining a bit of such a "sponge" under a magnifying glass, it will be seen that the skeleton is not composed of various pieces, but of one continuous mass of branching fibers, which interlace and unite in apparently the greatest confusion; yet in the living animal these were perfectly adapted to the position of the canals and the general needs of the animal.

Besides being a scaffold-work to which the fleshy portions of the body are fastened, the skeleton serves also for protection. In some species, needle-like spicules as fast as they are formed are partly pushed out over the entire surface of the body, giving the appearance of a spiny cactus; or in other cases they are arranged in tufts about the canals, effectually preventing the entrance of any marauder. Thus perfectly protected, the sponges have but few natural enemies, and hence it is that in favorable localities they grow in great profusion.

28. Race histories and life histories.—We have now traced living things from their simplest beginnings, where they exist as single cells, and have seen that in bygone times similar forms have united into simple colonies, and these

through a division of labor among the constituent cells have resulted in *Volvox*-like colonies. There are the strongest reasons for the belief that as these simple forms scattered into various surroundings and underwent changes to meet the shifting conditions, they assumed different degrees of complexity that have resulted in the animal forms of the present day.

It may have been noticed also that the sponge in its development passes through these stages: a single-celled egg; later, a young form similar to *Pandorina*, then growing to look like *Volvox*, and finally assuming its permanent form. The history of the race of sponges and their development through a long line of ancestry of increasing complexity is thus told by the sponge as it develops from the egg into the adult; and, so far as we know, all the many-celled animals in their growth from the egg repeat more or less clearly the stages passed through by their forefathers.

CHAPTER V

THE COELENTERATES

29. General remarks.—This division of the many-celled animals includes the jelly-fishes, sea-anemones, and corals. A few species live in fresh water, but the majority are confined to the sea, being found everywhere from the shoreline and ocean surface to the most profound depths. Adapted to different surroundings and modes of life, they constitute a vast assemblage of the most bewildering diversity. In some cases their resemblance to plants is remarkable, and the term zoophyte or “plant animal,” occasionally applied to them, is the relic of former times when naturalists confounded them with plants. Even to-day certain species are sometimes collected and preserved as seaweeds by the uninformed.

The general plan on which all coelenterates are constructed is a simple sac, in some respects resembling that of the lower sponges, yet, since the modes of life of the members of the two groups are usually quite unlike, we shall find many profound differences between them.

30. The fresh-water Hydra.—The bodily plan comes out most clearly in the *Hydra* (Fig. 16, A, D), which occurs upon the stems and leaves of submerged fresh-water plants in this and other countries. Its body, of a green or grayish color, according to the species, scarcely ever attains a diameter greater than that of an ordinary pin nor a length exceeding half an inch. One end of the cylindrical organism is attached to some foreign object by means of a sticky secretion, but as occasion requires it may free itself, and by

means of a "measuring-worm" movement travel to another place.

Examined under a hand lens, the free end of the body will be found to support six to eight prolongations known

as *tentacles*, which serve to convey food to the mouth, centrally located in their midst. This opening, unlike that of the sponges, is the only one leading directly into the large central gastric cavity which occupies nearly the entire animal (Fig. 16, D). As in the sponge, the cells of the body are arranged in the form of definite layers, but the middle one is represented only by a thin gelatinous sheet.

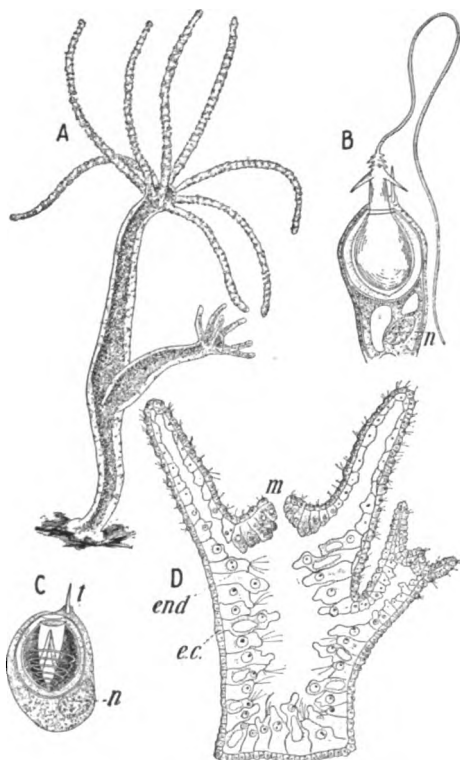


FIG. 16.—The fresh-water *Hydra*. A, entire animal, developing a new individual (enlarged 25 times). B, C, nettle-cells (after SCHNEIDER); D, section through the body.

31. Organs of defense. — These are the so-called *lasso* or *nettle-cells* (Fig. 16, C). Some

of the cells of the outer layer possess, in addition to the elements of the typical cell, a relatively large ovoid sac filled with a fluid, and also a spirally wound hollow thread

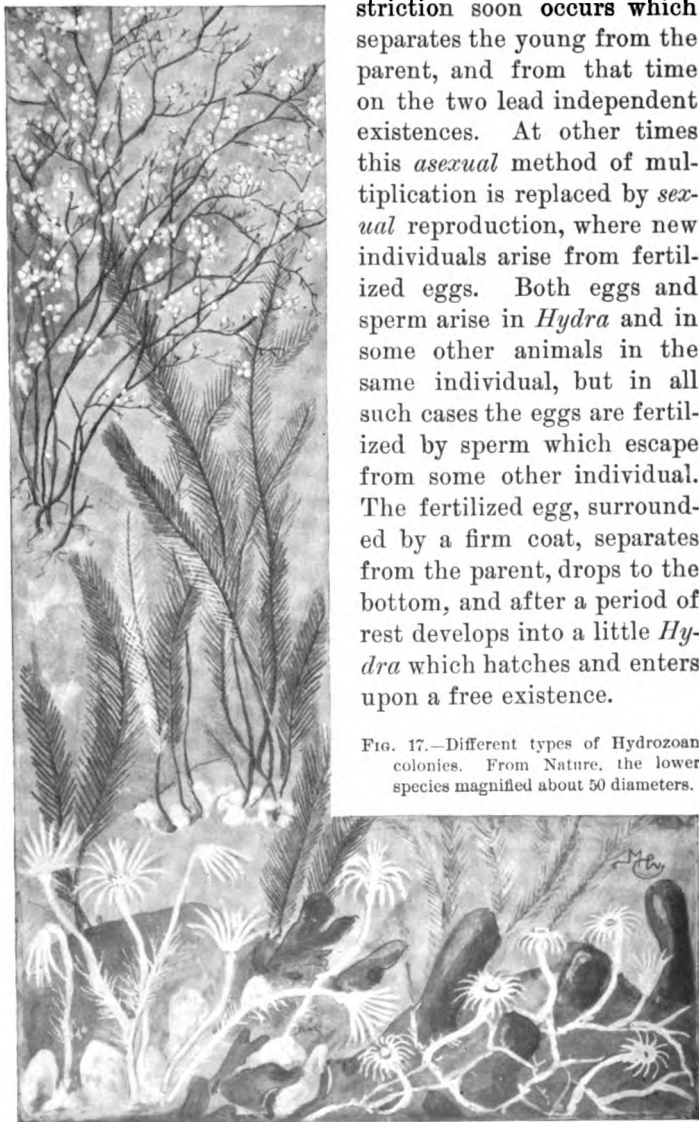
provided with barbs near its base. On the outer extremity of the nettle-cell projects a delicate bristle-like process, the *trigger hair*. These cells are especially abundant on the tentacles (Fig. 16, A, D), forming close, knob-like elevations or "batteries," thus rendering it practically impossible for any free-swimming organism to avoid touching them in brushing against the tentacles. In such an event the disturbances conveyed through the trigger hair set up in some unknown way very rapid changes in the cell. This causes the sac to discharge the coiled thread and barbs into the body of the intruder, which is rendered helpless by the paralyzing action of the fluid conveyed through the thread. Thus benumbed it is rapidly borne to the mouth and swallowed. In time new nettle-cells develop to take the place of those discharged and consequently worthless.

32. Digestion of food.—Upon the interior of the body of *Hydra* and all of the cœlenterates the food, by reason of its large size, is incapable of being taken into the various cells. It is necessary, therefore, to break it up into smaller masses, and this is accomplished through the solvent action of the digestive fluid poured over it from some of the cells of the adjacent inner layer. When subdivided, the granules swept about the gastric cavity by the beating of the flagella (Fig. 16, D) are seized by the processes on the free surfaces of the remaining inner layer cells, where they undergo the final stages of digestion; then in a dissolved state they become absorbed and assimilated by all the cells of the body.

33. Methods of multiplication.—Very frequently, especially if the *Hydra* has been well fed, two or three processes arising as outpushings of the body wall may be noted upon the sides of the animal (Fig. 16, A, D). If these be watched from time to time they are found to increase in size, and finally, upon their free extremities, to develop a mouth and surrounding tentacles. Up to this point growth has taken place as a result of the assimilation of nutritive substances supplied from the parent; but a con-

striction soon occurs which separates the young from the parent, and from that time on the two lead independent existences. At other times this *asexual* method of multiplication is replaced by *sexual* reproduction, where new individuals arise from fertilized eggs. Both eggs and sperm arise in *Hydra* and in some other animals in the same individual, but in all such cases the eggs are fertilized by sperm which escape from some other individual. The fertilized egg, surrounded by a firm coat, separates from the parent, drops to the bottom, and after a period of rest develops into a little *Hydra* which hatches and enters upon a free existence.

FIG. 17.—Different types of Hydrozoan colonies. From Nature, the lower species magnified about 50 diameters.



34. Hydrozoa, or Hydra-like animals.—Attention has already been directed to the fact that the structure of *Hydra* is the simplest of the coelenterates; nevertheless, the thousand or more species belonging to this class which present a much more complicated appearance (Fig. 17) possess many fundamental *Hydra*-like characters. It is owing to this fact that this assemblage of forms has been placed in the class of the Hydrozoa, or *Hydra*-like animals.

With but very few exceptions the members of this class are marine, usually living near the shore-line, where at times their plant-like bodies occur in the greatest profusion attached to rocks, seaweeds, or the bodies of other animals, particularly snails and crabs. Fig. 17 (upper colony) gives a good idea of one of the more complex forms, whose tree-like body attains in some cases the relatively giant height of from 15 to 25 c.m. (six to ten inches). In early life it bears a close resemblance to a *Hydra*. Buds form in much the same way, but they retain permanently their connection with the parent, and in turn bear other buds, until finally the form shown in the figure is attained. In the meantime root-like processes have been forming which afford firm attachment to the object upon which the body rests. Also during this process the cells of the outer layer form a horny external skeleton ensheathing the entire organism except the terminal portions (the hydranths, Fig. 18, B) bearing the tentacles. The gastric cavities of all communicate, and the food captured by one ministers in part to its own needs and, swept through the tubular stalks and roots, is also shared by all other members.

35. Jelly-fishes and the part they play.—During the process of growth a number of stubby branches arise which differ from the ordinary type in shape, and also in many cases as regards color. These club-like, fleshy portions develop close-set buds (Fig. 18, c) which early assume a bell-like shape, the point of attachment corresponding to the handle, while the clapper is represented by a short, slender

process bearing on its end an opening which becomes the mouth (Fig. 18, A). Around the margin of the bell numerous tentacles develop, and at the same time the gelatinous substance situated between the outer and inner layers of the bell expands to a relatively enormous degree, giving it an increasing globular form and glassy appearance.

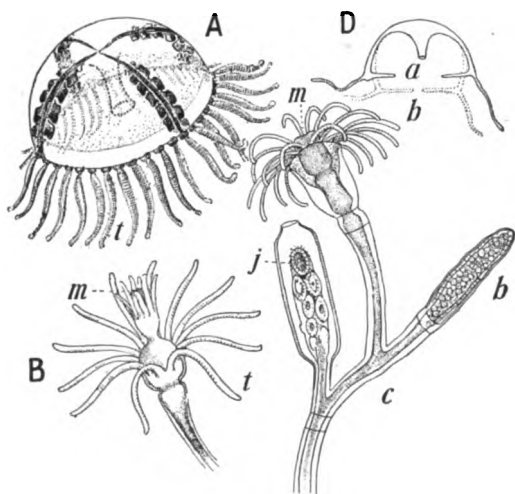


FIG. 18.—A jelly-fish (*Gonionemus*), slightly enlarged. The stalked mouth is shown in dotted outline. B, C, enlarged portions of a hydroid colony bearing the mouth and tentacles; j, a capsule within which the jelly-fish develop; D, diagram of jelly-fish, illustrating its method of locomotion.

Finally, vigorous movements rupture the connection with the parent, and this newly developed outgrowth, usually small, becomes an independent organism popularly termed a jelly-fish. While the external form of the jelly-fish appears to be widely different from the hydranths, a more careful study shows the difference to be superficial. Some zoologists believe that jelly-fishes are simply buds which have become fitted to separate and swim away from the colony in order to distribute the young, as described hereafter.

When the stalked colonies are very abundant the jelly-

fishes may be liberated in such multitudes that the upper surface of the ocean for many miles may be closely packed with them in numbers reaching far into the millions. In these positions they are carried both by oceanic currents and through the alternate expansion and contraction of the bell, a movement resembling the partial closing and opening of an umbrella. In the jelly-fish the contraction is more vigorous and rapid than the opening in the velum or veil (Fig. 18, *b*) which is so narrowed that the water in the subumbrella space (*a*) is driven through it with considerable force, which results in driving the body in the opposite direction.

The life of a jelly-fish is perhaps of short duration, lasting not more than a few hours in some species, up to two or three weeks in others, but during that period they produce multitudes of eggs which develop into minute free-swimming young. These settle down on some rock or seaweed, and soon develop a *Hydra*-like body which, after the fashion described above, grows into another tree-like colony.

36. Alternation of generations.—It will be noticed that the offspring of the jelly-fishes are not jelly-fishes, but stalked colonies, and these latter forms give rise to jelly-fishes. This is known as the *alternation of generations*, the jelly-fish generation alternating with the colonial form. This characteristic is of the greatest service in preventing the extermination of the race. Were the stalked forms to give rise directly to other stationary colonies, it is obvious that before long all the available space in the immediate locality would be filled. The food supply, always limited, would not suffice, and starvation of some or imperfect development of all would result; but by means of the free-swimming jelly-fish new colonies are established over very extensive areas, and favorable situations are held by all. /

37. More complex types.—As mentioned above, there are perhaps upward of a thousand species of Hydrozoa, all with

essentially the same structure but with various modes of branching (for some of the commoner modes, see Fig. 17). In some of the higher forms a division of labor has arisen among various members of the association which has led to most interesting results. For example, Fig. 19 represents a species of hydroid found investing the shells of sea-snails occupied by hermit crabs (Fig. 60). To the unaided eye its appearance is that of a delicate vegetable growth, but when placed under the microscope it is found to consist of

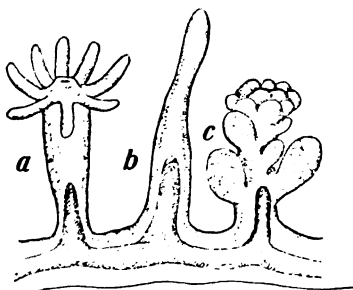


FIG. 19.—An enlarged portion of a hydroid colony (*Hydractinia*), showing (a) the nutritive polyp, (b) the defensive polyp, and (c) the reproductive polyp.

a multitude of *Hydra*-like animals united by a hollow branching root system connecting the gastric cavities of all of them (Fig. 19). Certain individuals (a) with tentacles and a mouth resemble a *Hydra*; others, without a mouth and tentacles, are reduced to a club-like form (b) liberally supplied with nettle-cells upon their free extremities; while the third type

(c), likewise devoid of a mouth, possesses rudiments of tentacles below which are borne numerous clumps of reproductive cells. The first type, the only one possessing a mouth, captures the food, and after digesting it distributes the greater portion to the remaining members by means of the connecting root system; those of the second form, defending the others by means of their nettle-cells against the inroads of a foreign enemy, are the soldiers of the colony; while the third type produces the eggs from which new individuals develop.

In some of the higher Hydrozoa, the Portuguese man-of-war (Fig. 20), this division of labor has reached a more advanced stage of development, and in addition the entire

colony is fitted for a free-swimming existence. What corresponds ordinarily to the attached stalk in other forms terminates in a bladder-like expansion, distended with gas, that serves as a float. From it are suspended individuals resembling great streamers sometimes many feet in length, without mouths, but loaded with nettle-cells that enable them to capture the food, which is conveyed to the second type, the nutritive polyps. Each of these is a simple tube bearing a mouth, and within them the food is digested and distributed by means of a branching gastric cavity extending throughout the entire colony. Then there are individuals like mouthless jelly-fishes which bear the eggs and care for the perpetuation of the colony; and besides these there may be some whose duty it is to defend the rest, and others whose active swimming movements, together with the wind, drive the colony about. Thus united, sharing the food supply and working for the general welfare of all, the members of this colony live in greater security and with less effort than if, as separate individuals, each was fighting the battles of life alone.

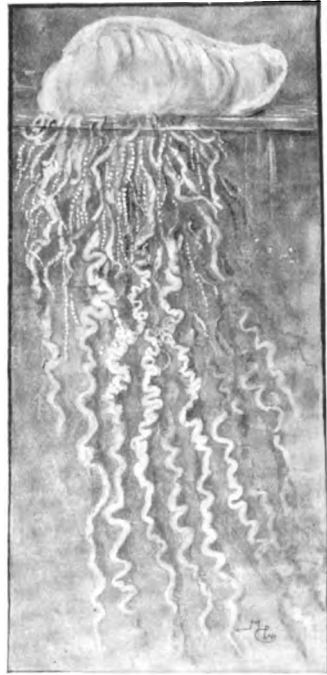


FIG. 20.—A colonial jelly-fish (*Physalia*).
From Nature.

38. Scyphozoa.—The greater number of the larger and more conspicuous jelly-fishes are included under this term. In general shape and locomotion they resemble those of the

preceding group (Fig. 21), but, while the latter are generally very small, these forms are commonly from four to twelve inches in diameter, and some measure one to two meters (three to six feet) across the bell. They are also distinguished by means of tentacles which extend from the corners of the mouth sometimes to a distance of several feet,



FIG. 21.—A jelly-fish (*Rhizostoma*), about one-fourth natural size.

and together with the marginal tentacles are formidable weapons for capturing small crabs, fishes, and other animals which serve as food. In turn these forms serve as the food of many whales, porpoises, and numerous fishes which hunt them down, though the amount of nourishment they contain is probably relatively small owing to the fact that in their composition there is a large percentage of water (99 per

cent in some species). The lobed margin of the bell, the absence of a definite swimming organ or velum, and the character of several of the internal organs, distinguish the larger from the smaller jelly-fish; but the greatest difference, however, is in the method of development.

39. Development.—The eggs arise from the inner layer of the jelly-fish and drop into the gastric cavity, where each develops into a ciliated two-layered sac in some respects like that of a young sponge. Swimming away from the parent, they finally settle down, and attaching themselves (Fig. 22, *a*) assume the external form and habits of the sea-

anemones, described in the next section. In the course of time remarkable changes ensue, which first manifest them-

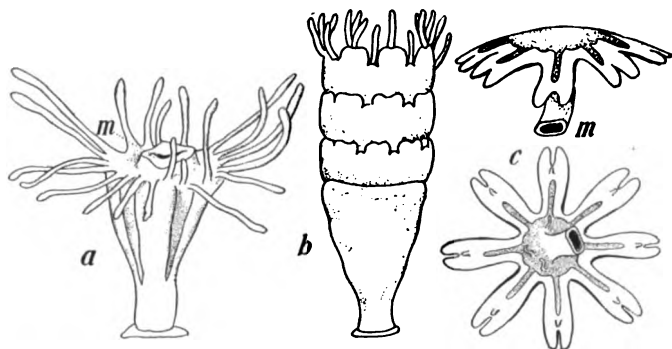


FIG. 22.—Stages in the development of a scyphozoan jelly-fish. *a*, the attached young, which in *b* has separated into a number of disks, each of which becomes a jelly-fish, *c*.—After KORSCHULT and HEIDER.

selves in a series of grooves encircling the body. These grow deeper, and the body of the animal finally comes to resemble a pile of saucers with the edge of each developed into a number of lobes (Fig. 22, *b*). One after another each saucer, to preserve the simile, raises itself from the top of the pile and swims away, and is clearly seen to be a jelly-fish, though considerably unlike the adult. As growth proceeds, however, it undergoes a series of transformations which result in the adult form.

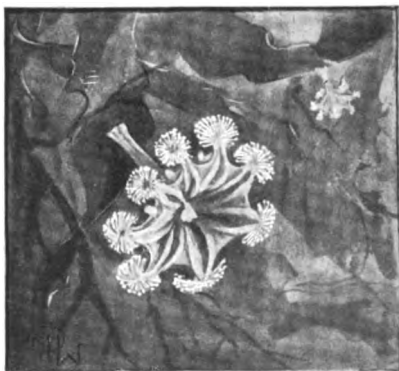


FIG. 23.—An attached scyphozoan jelly-fish (*Halicystus*). Natural size, from Nature.

40. **Sea-anemones.**—In its external appearance the sea-anemone (Fig. 24) bears some resemblance to the *Hydra*, but is of a much larger size (1 to 45 c.m., or $\frac{1}{2}$ inch to $1\frac{1}{2}$ feet in diameter), and is frequently brilliantly colored. The number of tentacles is also more numerous, and the mouth leads into the body by means of a slender esophagus (Fig. 25). Numerous partitions from the body wall extend inward, and many unite to the esophagus, keeping the latter

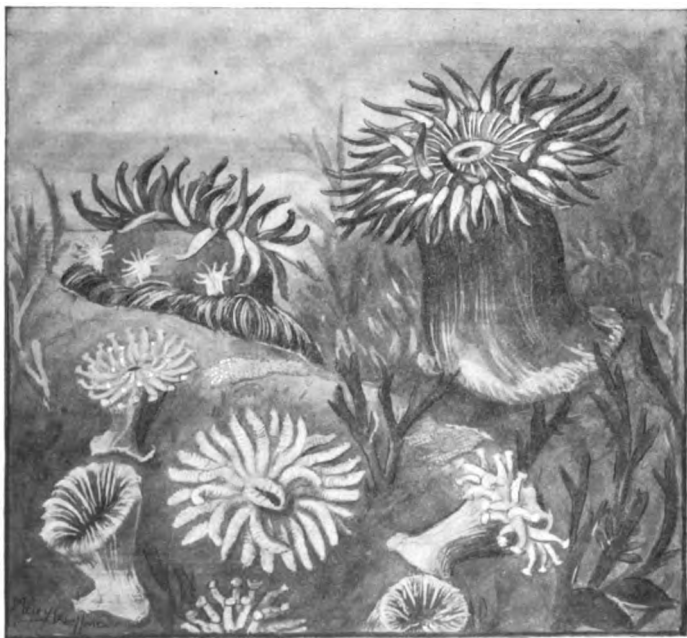


FIG. 24.—Sea anemones (the two upper figures) and solitary coral polyps.

in position. Below the esophagus each partition projects into the great cavity of the body and bears upon its inner free edge several important structures. The first of these, known as the mesenteric filaments (Fig. 25), appearing like delicate frills, plays an active part in the digestion of the food. Associated with these are long, slender threads,

closely packed with innumerable lasso-cells, which may be thrown out through openings in the body wall when the animal is attacked. Lasso-cells are also very numerous on the tentacles, which are thus to some extent defensive, but are chiefly active in capturing the crabs and small fish which serve as food.

The partitions also carry eggs which may undergo the first stages of their growth within the body, and when finally able to swim are sent out through the mouth opening by hundreds to seek out favorable situations, there to settle down and remain. In some species the young may sometimes arise as buds, as in *Hydra* (Fig. 24), and in others the animals have been described as splitting longitudinally into two equal-sized young.

41. Corals.—The coral polyps also belong to this group, showing a very close resemblance to the sea-anemones. In most cases they develop a firm skeleton of lime, commonly known as "coral," which serves to protect and support the body. In a few species the polyps throughout life are solitary, and with skeleton comparatively simple (Fig. 24); but the larger number of species become more complex by developing buds, which retain their connection with the parent, and in turn produce other outgrowths with the ultimate result that highly branched

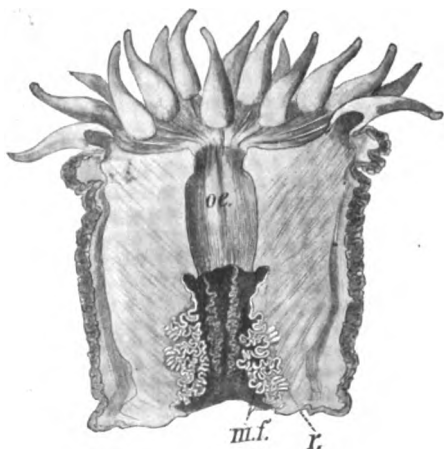


FIG. 25.—Longitudinal section through the body of a sea-anemone. *oe.*, esophagus; *m. f.*, mesenterial filaments; *r.*, reproductive organs.

colonies are produced (Fig. 26). At the same time the outer layer of the body is continually forming a skeleton which encloses the colony as a sheath, except at the termination of each branch, where the mouth and tentacles are located. In certain species—for example, the sea pens (*Pennatula*) and sea fans (*Gorgonia*)—a skeleton may be

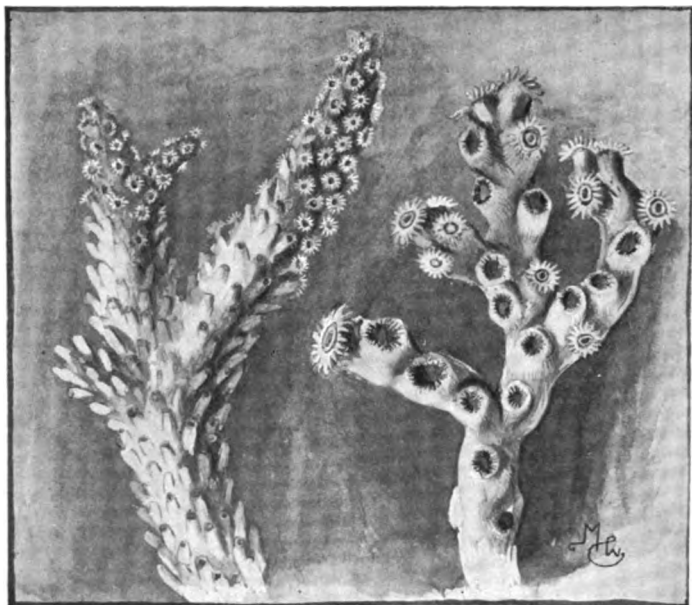


FIG. 26.—Small portions of coral colonies, with some of the polyps expanded.

formed of myriads of lime spicules, somewhat like those of the sponge, which are bound together by the fleshy substance of the body; but the skeleton of most of the common forms in the ocean, and the coral found in general collections, is stony. According to their method of branching, such specimens have received various popular names, such as brain, stag-horn, organ-pipe, and fungus corals.

Nearly all species, like the sea-anemones, are brilliantly colored during life, and several are highly phosphorescent. All are marine, and while they are found everywhere, from the shore-line to great depths, the more abundant and larger species inhabit the clear, warm waters of the tropics down to a depth of one hundred and sixty feet. In such regions the stag-horn corals especially grow in the wildest profusion, and become tall and greatly branched. Except in quiet water they are continually being broken by the waves, beaten into fragments, and the resulting sand is deposited about their bases. As a result of this continuous growth and erosion, there have been formed from coral sand mixed with the shells of mollusks and the skeletons of various Protozoa several of the islands along the Florida coast and many of those of the Pacific, some of them hundreds of miles in extent.

CHAPTER VI

THE WORMS

42. General Characteristics.—The bodies of the animals comprising the two preceding groups are exposed on all sides equally to the water in which they live and are radially symmetrical; but in the worms, one side of the body is fitted for creeping, and for the first time we note a well-marked dorsal (back) and ventral (under) surface. In the former, the body, like a cylinder, may be divided into similar halves by any number of planes passing lengthwise through the middle; but in the worms, the right and left halves only are exposed equally to their surroundings, and there is, accordingly, only one plane which divides the body into corresponding halves, so that these animals, like all higher forms, are bilaterally symmetrical. In creeping, also, one end of the body is directed forward and it thus becomes correspondingly modified. It usually bears the mouth, and may be provided with eyes, feelers, or organs of touch, and various other structures which enable the worm to recognize the nature of its surroundings. The nervous and muscular systems are better developed than in the foregoing groups, and we note a greater vigor and definiteness in the animal's movements, and in various ways the worms appear better able to avoid or ward off their enemies, recognize and select their food, and in general adapt themselves to the conditions of life.

The division of the worms is a very large one, and in some respects difficult to define, owing to the close resem-

blance which many of them show to animals in other groups. All the invertebrates, therefore, except the crabs and insects, were placed in one group until subsequent study made it possible to classify them more exactly. According to the general shape of the body, and the arrangement of internal organs, worms are divided into a number of groups, chief among which are the flatworms, the thread or roundworms, and the ringed worms or annelids.

THE FLATWORMS

43. Form and habitat.—The flatworms, as their name indicates, are much flattened, leaf-like forms, some species living in damp places on land, in fresh-water streams or ponds, or along the seacoast, while a variety of other species are parasitic. The free forms (Fig. 27) are usually small, barely reaching a length greater than five or seven centimeters (2 to 3 inches), but some of the parasitic species (Fig. 31) attain the great length of six to thirteen meters (20 to 40 feet).

The free-living forms usually occur on the under side of stones, and frequently are so delicate that a touch is sufficient to destroy them. A few species are almost transparent, while many are colored to harmonize completely with their surroundings, so that, even though fragile and defenseless, they escape the attacks of enemies by being overlooked. The night-time or dark days are their hunting

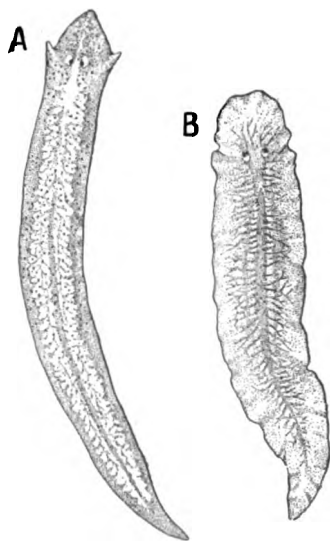


FIG. 27.—A, fresh-water flatworm (*Planaria*); B, marine flatworm (*Leptoplana*). Enlarged, from Nature.

season, and at such periods they may be found moving about with a steady gliding motion (due to cilia covering the entire body), varied occasionally by a looping, caterpillar movement, or by swimming with a flapping of the sides of the body. When watched at such times they may sometimes be seen to snatch up small worms, snails, small crabs and insects, which serve as food.

More closely examining one of these forms, for example, the species usually found on the under side of sticks and stones in our shallow fresh-water streams (Fig. 27, A), we note that the forward end is not developed into a well-defined

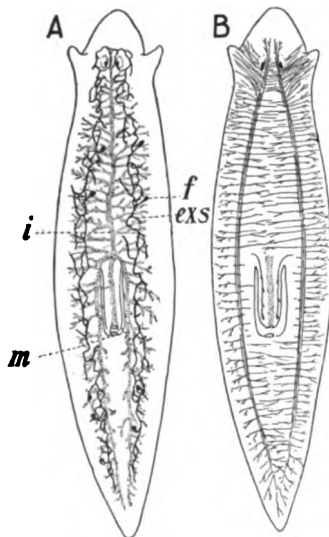


FIG. 28.—Anatomy of fresh-water flat-worm (*Planaria*). *exs.*, excretory system, with flame-cell (*f*). The alimentary canal is stippled. B, nervous system.

head as in the higher worms, but is readily determined by the presence of very simple eyes and tentacles, while the lower creeping surface is distinguished by a lighter color and the presence of the mouth. Through this small opening a slender proboscis (in reality the pharynx) may be extended some distance, and may be seen to hold the small organisms upon which it lives until they are sufficiently digested to be taken into the body.

44 Digestive system.—In the smaller flatworms, some of which are scarcely larger than many of the Protozoa, the alimentary canal is a simple unbranched tube; but in the larger forms such an ap-

paratus is replaced by a greatly branched digestive tract which furnishes an extensive surface for the rapid absorp-

tion of food, and extending deep into the tissues of the body, carries nutriment to otherwise isolated regions. In the fresh-water forms and their allies there are three main branches of the intestine (Fig. 28), while in many of those from the sea there are several, and their arrangement affords a basis for their general classification.

45. Excretory system.—In the sponges and cœlenterates the wastes are cast out by the various cells into the gastric cavity or at once to the exterior without the aid of any pronounced system of vessels; but in the flatworms several of the organs are deeply buried within the tissues of the body and a drainage system becomes a necessity. This consists of a paired system of vessels extending the length of the animal (Fig. 28) and provided with numerous branches, some of which open at various points on the surface of the body, while the others terminate in spaces (Fig. 29, *s*) among the organs in what are known as flame-cells. The substances which accumulate in these spaces are gathered up by the flame-cell, poured into the space it contains, and by means of the vibratory motion of its flagellum (*f*), a movement bearing a fancied resemblance to the flickering of a flame in the wind, are borne through the tubes to the exterior.

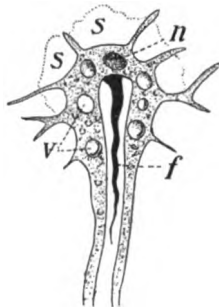


FIG. 29.—Flame-cell of flatworm (after LANG). *f*, flagellum; *n*, nucleus; *s*, spaces among the organs of the body; *v*, waste materials.

46. Nervous system and sense-organs.—In the sponges no definite nervous system is known to exist, the slight movements which the cells are able to undergo being regulated somewhat as they are in the Protozoa. Among the cœlenterates certain of the cells scattered over the surface of the body are set aside as nerve-cells, and, more or less united by means of fibers extending from them, convey impulses over the body. In the flatworms the larger number of nerve-cells

are collected into two definite masses (Fig. 28, B), which constitute a simple brain on which the eyes are situated and from which bundles of nerve fibers pass to all parts of the body, the two extending backward being especially noticeable. As in the squirrel, these are distributed to the muscles and other organs to regulate their activity, while those distributed to the skin, especially in the forward part of the body, convey stimuli produced by touch. The branches connecting with the eyes enable the animal to distinguish light from darkness, but are probably too simple to allow it to clearly distinguish objects of the outside world. The sense of smell and possibly that of taste are also present, but are relatively feeble.

Some other characters of this class will be noted in the consideration of the two following classes.

47. Parasitic flatworms (trematodes)—parasitism.—Mention has already been made of the associations of two animals as "messmates" for mutual benefit, such as the *Hydractinia* growing on the surface of the shell inhabited by the hermit crab, to which it gives protection by means of its nettle-cells, while in turn being borne continually into regions abounding with food. More frequently, however, one animal derives benefit from another without making any compensation. For example, many species of flatworms live within the shells of certain snails and upon the bodies of sea-urchins and starfishes, where they gather in their food supply safe from the attacks of enemies. Such associations are probably without much if any inconvenience to the animal thus inhabited, and it also appears probable that the tenants are transients, using the mollusk or starfish only as a temporary home. But from this condition of affairs it is only a short step to the parasitic habit, where the association becomes permanent and the occupant is provided with various structures which prevent its separation from its host. This latter kind of union occurs throughout the group of trematodes; all are parasitic, and

their internal organization, so closely resembling that of the free-living forms as to need no further description, indicates that they are descendants of the latter. In the greater number the body is flat, and a few species still retain their outer coat of cilia; but since these are no longer of service as locomotor organs they have generally disappeared, and in their place numerous adhesive organs, such as spines, hooks, and suckers (Fig. 30), have arisen, which enable the animals to hold on with great tenacity. Thus attached to its host, and using it as a convenient and comparatively safe means of locomotion, the parasite may still

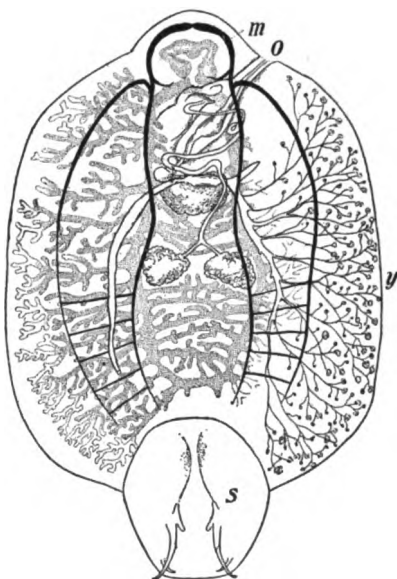


FIG. 30. — A parasitic flatworm (*Epidella*). *m*, mouth; *o*, opening of reproductive system; *s*, sucker and spines for attachment. The digestive system is stippled; nervous system black. Enlarged 8 times, from Nature.

continue to capture small animals for food or may derive its nourishment from the tissues of the host. In addition there are numbers of internal parasites, living almost exclusively in the bodies of vertebrate animals, scarcely a single one escaping their ravages.

48. Life history.—In the external parasites the young hatch out and with comparative ease make their way to another host; but the young of an internal parasite, inhabiting the alimentary canal, have a very slight chance indeed of ever reaching a similar location in another host.

For this reason an almost incredible number of eggs is laid, and some extraordinary measures are employed in effecting the desired result. Probably the best-known example is that of the liver fluke inhabiting the bile-ducts in the sheep. Each worm lays several hundred thousand eggs, which make their way from the host, and if they chance to fall in pools of water or damp situations may proceed to develop, otherwise not. If the surroundings be favorable, the young, like little ciliated Infusoria, escape from their shells and restlessly swim or move about for a short time, and if during this time they come in contact with certain species of snails living in these situations they at once bore into their bodies. Here they produce other young somewhat resembling a tadpole, that now make their escape from the snail. In a short time each one crawls upon a blade of grass, and surrounds itself with a tough shell, where it may remain for several weeks. If the grass on which they rest be eaten by a sheep, they finally make their way to the bile-ducts and there become adult. The life cycle is now complete; the young form has found a new host; and the process shows how wonderfully animals are adapted to the conditions which surround them, and how closely they must conform to these conditions in order to exist.

49. **The tapeworms (cestodes).**—The cestodes, or tapeworms, are also parasitic flatworms in which the effects of such a mode of life are strongly marked. They occur almost exclusively in the bodies of vertebrate hosts and exhibit a great variety of bodily forms, in some cases resembling rather closely the trematodes, but in others strikingly different. In the latter type the body is usually of great length (from a few centimeters to upwards of sixteen meters (50 feet)), and terminates in a "head" (Fig. 31) provided, in the different species, with a great variety of hooks and spines and numbers of suckers for its attachment to the body of the host. From the head the body extends backward in the gradually enlarging ribbon-like body, slender at

first and scarcely showing the segments which finally become so prominent a feature.

When carefully examined, a two-lobed brain is found in the "head," and from it nerves extend the entire length of the body, followed throughout their course by the tubes of the excretory system; also each segment contains a perfect reproductive system, so that even if it be separated from the others it may continue to exist for a considerable length of time. Furthermore, the tapeworms are surrounded by the predigested fluids of their host; a special alimentary canal is therefore superfluous, and all traces of it have disappeared.

50. Development.—As the animal clings in this passive way to the body of its host the segments, loaded with eggs ready for development, separate one after another from the free end of the body, pass to the exterior, and slowly crawling about like independent organisms, lay great numbers of eggs, which may find an intermediate host as in the life cycle of the liver fluke, and so in time find their permanent resting-place. Fortunately in all these parasitic forms, though an inconceivably great number of eggs are laid, only a comparatively few reach maturity. Even these, however, may cause at times great destruction among the higher, and especially our domestic, animals, often doing damage amounting to many millions of dollars per year.

51. The tapeworm in relation to regeneration.—It has been known for more than one hundred and fifty years that some of the lower animals possess to a surprising degree the ability to regenerate parts of the body lost through injury. The *Hydra*, hydroids, and some of the jelly-fishes



FIG. 31.—Tapeworm (*Taenia solium*). In upper left-hand corner of figure is the much enlarged head. —After LEUCKART.

may be cut into a number of pieces, each of which will develop into a complete individual; and this power of recovery from the injuries produced by enemies is of the greatest service in the perpetuation of the species. This ability is also present in certain flatworms, and some species are known which voluntarily separate the body into two portions, each of which becomes an adult. In other species a similar process results in the formation of a chain of six individuals, placed end to end, the chain finally breaking up into as many complete worms. It is possible that the tapeworm may also be looked upon as a great chain of united individuals produced by the division of a single original parent, which becomes adapted for attaching the others until they separate. These latter are capable only of a very sluggish movement, and, devoid of mouth and alimentary canal, are not able to digest their food, but their life work is to so lay their eggs that they may develop into other individuals, and for this they are well adapted. /

NEMATODES (THREADWORMS)

52. General characters.—This class of worms is composed of an enormous number of different species, some parasitic, others free all or a portion of their lives, and in view of the fact that they inhabit the most diverse situations it is remarkable that they are so uniform in their structure. In all the body is slender, and the general features of its organization may be readily understood from an examination of the “vinegar eel” (Fig. 32, A). This small worm (not an eel), a millimeter or two in length, lives on the various forms of mold that grow in fermenting fruit juices, especially after a little sugar or paste has been added. A tough cuticle surrounds the body, preserving its shape and at the same time protecting the delicate organs against the action of the acids in which it lives. Through this may be seen great bands of muscles extending the entire length of the body and producing the wriggling movements of swimming

or crawling. They also give support to a brain, which is in the form of a collar encircling the pharynx near the head, and to the great nerves which extend from it. Still further within the transparent body the alimentary canal may be distinguished as a straight tube passing directly through the animal. The alimentary canal lies freely in a great space, the body cavity, traces of which may exist in the flatworms in the form of hollow spaces into which the kidneys open. It is possible that in this form also the kidneys open into this space, and it is roomy enough besides to afford lodgment for the reproductive organs in addition to a large amount of fluid which is probably somewhat of the nature of blood. A space in some respects similar to this occurs in all the animals above this group, and as we shall see, it is often curiously modified and serves for a number of different and highly important purposes. In the roundworms the fluid it contains probably acts in the nature of a blood system, distributing the food and oxygen to various parts of the body and carrying the wastes to the kidneys for removal.

53. Multiplication.—In the matter of the production of new individuals the greatest differences exist. In some threadworms, for example the "vinegar eel," eggs develop within the body and the young are born with the form of the parent. In other cases the eggs are laid in the water, where they, too, may directly grow to the adult condition; but in

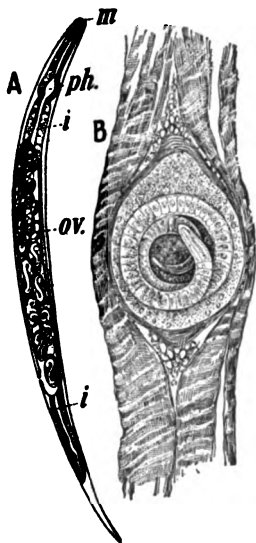


FIG. 32.—Thread- or roundworms. A, vinegar eel (*Anquillula*); m, mouth; ph., pharynx; i, intestine; ov., developing young. B, *Trichina*. From Nature, greatly enlarged.

the greater number of species the development is roundabout, and one or more hosts are inhabited before the young assume the adult condition. Such is the case with the dreaded *Trichina* (Fig. 32, B), which infests the bodies of several animals, particularly the rat. When these forms are introduced into the alimentary canal of the rat, for example, they soon lay a vast quantity of eggs, sometimes many millions, which develop into young that bore their way into the muscles of the body, where they may remain coiled up for years. If the body of the rat be eaten by some carnivorous animal, these excessively small young are liberated during the process of digestion and rapidly assume the adult condition in the alimentary canal, likewise giving rise to young which pursue again this same course of development.

Another example of a complicated life history is in the *Gordius* or "horsehair snake" (a true worm and not a snake) frequently seen in the spring in pools where it lays its eggs. These eggs develop into young which bore their way into different insect larvæ, which are in turn eaten by some spider or beetle, and the worm thus transferred to a new host. In this they grow to a considerable size, and then make their exit from the body of the host and finally become adult.

54. Spontaneous generation.—It is only within comparatively recent years that such life histories have been understood. Formerly the sudden appearance of these and other forms in various situations were accounted for on the ground that they arose spontaneously without the intervention of any living creature. Even yet we hear of the transformation of horsehairs into hairworms, and of frogs, earthworms, and several other animals from inorganic matter, but such assertions are based on superficial observations, and at the present time no exception is known to the law that living creatures arise from preexisting living parents. "All life from life" (*omnium vivum ex vivo*) is a universal law.

ANNELIDS OR SEGMENTED WORMS

55. **The earthworms and their relatives.**—Leaving the groups of the parasitic animals, which have been driven from the field of active existence and in many ways are degraded by such a mode of life, we pass on to the higher free-living worms, where brilliant colors, peculiar habits, or remarkable adaptations render them peculiarly interesting. In considering first their general organization, we may use the earth-



FIG. 33.—Earthworm (*Lumbricus terrestris*). *m*, mouth ; *c*, girdle or clitellum.

worm (Fig. 33) (sometimes called angle-worm or fish-worm) as a type because of its almost universal distribution.

The body is cylindrical, shows well-marked dorsal and ventral surfaces, and, as in all of the annelids, is jointed, each joint being known as a *segment*. Anteriorly it tapers to a point, and the head region bearing the mouth is ill-defined, unlike many sea forms, yet serves admirably for tunneling the soil in which all earthworms live. In this process the animal is also aided by bristles or *setæ* which project from the body wall of almost every segment and may be stuck into the earth to afford a foothold.

56. **Food and digestive system.**—The earthworms are nocturnal animals, seldom coming to the surface during the day except when forced to do so by the filling of their tunnels with water or when pursued by enemies. At night they usually emerge partially, keeping the posterior end of the body within the burrow, and thus they scour the surrounding areas for food, which they appear, in some cases at least, to locate by a feeble sense of smell. They also frequently extend their habitations, and in so doing swallow enormous quantities of earth from which they digest out any nutritive substances, leaving the indigestible matter in

coiled "castings" at the entrance of the burrows. In thus mixing the soil and rendering it porous they are of great service to the agriculturist.

Although earthworms are omnivorous they also manifest a preference for certain kinds of food, notably cabbage, celery, and meat, which leads us to think that they have a sense of taste. All these substances are carried into their retreats and devoured, or are used to block the entrance during the day. The food thus carried into the body is digested by a system (Fig. 34) composed of several portions,

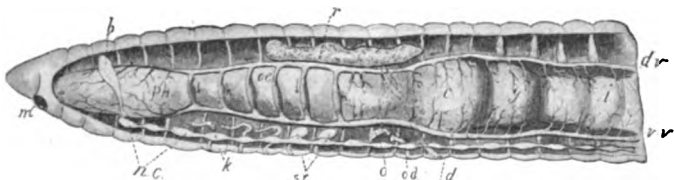


FIG. 34.—Earthworm (*Lumbricus*) dissected from left side. *b*, brain; *c*, crop; *d*, outer opening of male reproductive system; *dr*, dorsal blood-vessel; *g*, gizzard; *h*, pulsating vessels or "hearts"; *i*, intestine; *k*, kidney; *m*, mouth; *n. c.*, nerve-cord; *oe*, esophagus; *o*, ovary; *od*, oviduct; *ph*, pharynx; *r*, testes; *s. r.*, seminal receptacles; *v. v.*, ventral vessel.

each of which is modified for a particular part in the process. The mouth (*m*) leads into a muscular pharynx (*ph*) whose action enables the worm to retain its hold on various objects until swallowed, and this in turn is continuous with the esophagus. From here the food is passed into the thin-walled crop (*c*), and from this storehouse is gradually borne into the gizzard (*g*), whose muscular walls reduce it to a fine pulp now readily acted upon by the digestive fluids. These, resembling in their action the pancreatic juice of higher animals, are poured out from the walls of the intestine into which the food now makes its way; and as it courses down this relatively simple tube the nutritive substances are absorbed while the indigestible matters are cast away.

57. Circulatory system.—In all the groups of animals up to this point the digested food is carried through the body by a simple process of absorption, or in the threadworms by

means of the fluid in the body cavity ; but in the earthworm the division of labor between different parts of the body is more perfect, and a definite blood system now acts as a distributing apparatus. This consists primarily of a dorsal vessel lying along the dorsal surface of the alimentary canal (Fig. 34), from which numerous branches are given off to the body wall, and to the digestive system through which they ramify in every direction before again being collected into a ventral vessel lying below the digestive tract. In some of the anterior segments a few of the connecting vessels are muscular and unbranched, and during life pulsate like so many hearts to force the blood over the body, forward in the dorsal vessel, through the "hearts" into the ventral vessel, thence into the dorsal by means of the small connecting branches.

Some of the duties of this vascular system are also shared by the fluid of the body cavity, which is made to circulate through openings in the partitions by the contractions of the body wall of the animal in the act of crawling. In this rough fashion a considerable amount of nutritive material and oxygen are distributed to various organs, and wastes are carried to the kidneys to be removed.

58. **Excretion.**—In nearly all of the segmented worms there is a pair of kidneys to every segment (Figs. 34, 35). Each consists of a coiled tube wrapped in a mass of small blood-vessels, and at its inner end communicating with the body cavity by means of a funnel-shaped opening. In some unknown way the walls of the kidney extract the waste materials from the blood-vessels coursing over it and pass them into its tubular cavity. At the same time the cilia about the mouth of the funnel-shaped extremity are

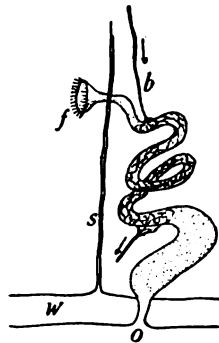


FIG. 35.—Diagram of earthworm kidney. *b*, blood-vessel ; *f*, funnel opening into body cavity ; *o*, outer opening ; *s*, septum ; *w*, body wall.

driving a current from the body-cavity fluids, which wash the wastes to the exterior.

59. **Nervous system.**—The nervous system of the earthworm consists first of a brain composed of two pear-shaped masses united together above the pharynx (one shown in Fig. 34), from which nerves pass out to the upper lip and the head, which are thus rendered highly sensitive. Two other nerves also pass out from the brain, and, coursing down on each side of the pharynx like a collar, unite below it and extend side by side along the under surface of the digestive system throughout its entire extent. In each segment the two halves of this ventral nerve-cord are united by a nerve, and others are distributed to various organs, which are thus made to act and in proper amount for the good of the body as a whole.

In its relation to the outside world the chief source of information comes to the earthworm through the sense of touch, for definite organs of sight, taste, and smell are but feebly developed, while ears appear to be entirely absent. Nevertheless these are sufficient to enable it to lead a successful life, as is evidenced by the great number of such worms found on every hand.

60. **Egg-laying.**—In digging up the soil where earthworms abound one frequently finds small yellowish or brownish bodies looking something like a grain of wheat. These are the cocoons in which the earthworms lay their eggs, and the method by which this is performed is unique. We have already noted the presence of a swollen girdle (the *clitellum*) about the body of the worm. At the breeding season this throws out a fluid which soon hardens into an encircling band. By vigorous contractions of the body this horn-like collar is now slipped forward, and as it passes the openings of the reproductive organs the eggs and sperms are pushed within it. They thus occupy the space between the worm and the collar, and when the latter is shoved off over the head its ends close as though drawn to-

gether by elastic bands. A sac, the cocoon, is thus produced, containing the eggs and a milky, nutritive substance. In a few weeks the worm develops and, bursting the wall of its prison, makes its escape.

61. **Distribution.** — The earthworms and their allies are found widely distributed throughout the world, and all exhibit many of the characters just described. The greatest differences arise in their mode of life: some are truly earthworms, but others are fitted for a purely aquatic existence in fresh water or along the seacoast; a few have taken up abodes in various animals and plants, and in some of these situations they extend far up the sides of the higher mountains. In all, the head is relatively indistinct, the number of bristles on each segment few, and for this and other reasons all are included in the subclass Oligochæta, or “few-bristle” worms.

62. **Nereis and its allies.**—In many of the above-mentioned situations members of a more extensive group of worms are found, with highly developed heads and many bristles arranged along the sides of the body. These are the Polychætes or “many-bristle” worms, and as a representative we may take *Nereis* (Fig. 36), a very common

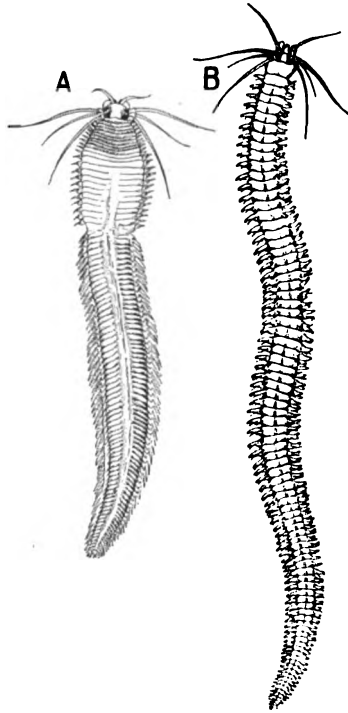


FIG. 36.—A marine worm (*Nereis*). A, appearance at breeding season, and B, at other times.

form along almost any seashore. The body presents the same segmented appearance as the earthworm, but the head (Fig. 37, A) is provided with numerous sense organs, chief among which are four eyes and several tentacles or "feelers."

The segments behind the head

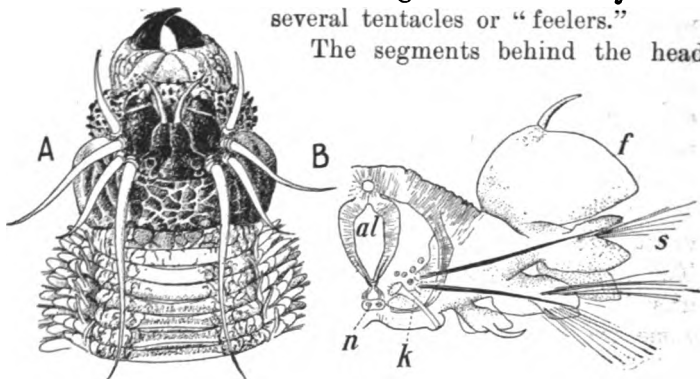


FIG. 37.—A, head and one of the lateral appendages (B) of a marine worm (*Nereis brandtii*); *al*, intestine; *f*, "gill"; *k*, kidney; *n*, nerve cord; *s*, bristles for locomotion.

differ very little from one another, and, unlike those of the earthworm, each bears a pair of lateral plates (Figs. 36, 37, B) or paddles with many lobes, some of which bear numerous bristles. By a to-and-fro movement these organs aid in pushing the animal about, or may enable certain species to swim with considerable rapidity.

As in all other worms, respiration takes place through the surface of the body, the area of which is increased by the development, on certain portions of the paddles (parapodia), of plates penetrated with numerous blood-vessels, which thus become special respiratory organs or gills (Fig. 37, B).

In their internal organization the Polychætes are constructed practically on the same plan as the earthworms, the principal difference being in the reproductive system. In the earthworm this is restricted to some of the forward segments, while in the present group the eggs and sperms

are developed in almost every segment, whence they are finally swept to the exterior through the tubes of the kidneys (Fig. 37, B).

The Nereis and its immediate relatives are all active forms, and by means of powerful jaws, which may be quickly extended from the lower part of the mouth cavity, they capture large numbers of small crustaceans, mollusks, and worms which happen in their path. Others more distantly related make their diet of seaweed, and many living on the sea bottom swallow great quantities of sand, from which they absorb the nutritious substances.

63. Sedentary forms.—Preyed upon by many enemies, a large number of species have been forced to abandon an active existence save in their early youth, and to construct many interesting devices for their protection. Numerous species, shortly after they commence to shift for themselves, build about their bodies tubes of lime (Fig. 39), from which they may emerge to gather food and into which they may dash in times of danger. As the worm grows the tube is correspondingly enlarged, and these tubes, in all stages of construction and variously coiled, may be found on almost every available spot at the seashore, and may often be seen on the shells of oysters in the markets.

In other species the tube is like thin horn, and may be further strengthened or concealed by numerous pebbles, bits of carefully selected seaweeds, or highly tinted shells, which give them a very attractive appearance. Such species usually develop out of immediate contact with other forms, but a few live so closely associated together that their twisted tubes



FIG. 38.—A common marine worm (*Polynæ brevisetosa*), with extended proboscis and overlapping plates covering the back.

form great stony masses, sometimes several feet in diameter.

64. **Effects of an inactive life.**—In many species such a sedentary life has resulted in the almost complete disappearance of the lateral appendages, which therefore no longer serve as organs of respiration, and this function has been shifted accordingly on to other structures. These new organs are situated principally on the exposed head,



FIG. 39.—Sedentary tube-dwelling marine worms, upper left hand *Sabella* (one-half natural size), the remainder *Serpula* (enlarged twice). From life.

and Fig. 39 shows the general appearance of some common species. The corners of the mouth have expanded into great plumes, sometimes wondrously colored like a full-blown flower, and these, bounteously supplied with blood-vessels, act as gills. When disturbed, the plumes are hastily withdrawn into the tube, and some of the so-called serpulids (Fig. 39, bottom of figure) close the entrance with a funnel-shaped stopper. While the plumes are primarily respiratory organs, they also act as delicate feelers, and may even bear a score or more of eyes; and in addition, being

covered with cilia, create the currents of water which bring minute organisms serving as food within reach of the mouth.

65. Development.—Unlike the earthworms, the Polychætes lay their eggs in the sea water, where they are left alone to develop as best they may. Both the male and female *Nereis*, as the egg-laying time approaches, undergo remarkable changes in their external appearance, resulting in the form shown in Fig. 36, A. They are now active swimmers, and thus are able to scatter the fertilized eggs over wide and more or less favorable areas. The young also for a time are free-swimming, but finally end their migrations by settling to the sea bottom, where they gradually attain the adult condition.

As in some of the flatworms, reproduction may also occur asexually by the division of the animal into two or more parts, each of which subsequently becomes a complete individual. In other species growth of various parts may result in two complete worms at the time of separation; and from such forms we may trace a fairly complete series up to those in which the original parent breaks up into twenty to thirty young.

66. The leeches.—At first sight the leeches (Fig. 40), or at least the smaller, more leaf-like forms, might be mistaken for flatworms, especially for some of the parasitic species. As in the latter, the mouth is surrounded by a sucker, and another is located at the hinder end of the body, but beyond this point the resemblance ceases. The

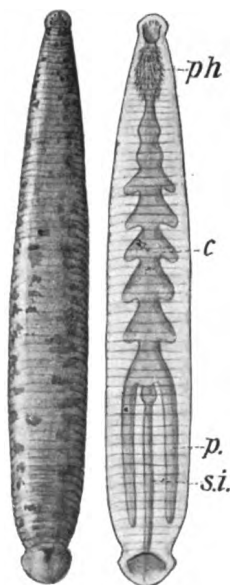


FIG. 40.—A leech (*Macrobodela*). Right-hand figure illustrates alimentary canal. *ph*, pharynx; *c*, crop; *p.*, lateral pouches; *s.i.*, intestine.

outer surface is delicately marked off into eighty or a hundred rings, of which from three to five are included in one of the deeper true segments corresponding to those of other annelids. From two to ten pairs of simple eyes are borne on the head, and owing to the fact that they are active swimmers, or move by caterpillar-like looping, locomotor spines are unnecessary and absent. In their internal organization, however, there are many features which indicate a close relationship with the Oligochætes or few-bristle worms. The nervous, circulatory, and certain characteristics of the excretory systems are decidedly similar, but, on the other hand, there are some facts difficult to explain, which have led some zoologists to believe that the relationship of these animals can not at present be determined.

67. Haunts and habits.—The leeches usually dwell in among the plants in slowly running streams, but some occur in moist haunts on land, and a considerable number live in the sea. All are “bloodsuckers”—fierce carnivorous worms, whose bite is so insidiously made that the victim frequently is ignorant of their presence. Fishes, frogs, and turtles are the most frequently attacked, but cattle and other animals which come down to drink also become their prey. In some of the tropical countries the land-leeches are present in large numbers secreted among the leaves, and so severe are their attacks that various animals, even man, succumb to their united efforts. Adhering by their suckers, they puncture the skin, some using triple jaws, and fill themselves until they become greatly distended, when they usually drop off and digest the meal at leisure. In certain species the intestine is provided with lateral pouches (Fig. 40), which serve to store up the food until the time for digestion arrives. A full meal is sufficient with some species to last for two or three months, and the medicinal or horse-leech when gorged with food may consume a year in digesting it.

68. **Egg-laying.**—The eggs of some leeches are stored up in a cocoon like that of the earthworm, which is attached to submerged plants or placed under stones. When the young are able to lead independent lives they emerge with the form of the parent. A leaf-like form, *Clepsine*, sometimes found adhering to turtles, fastens the eggs to the under side of its body, and the young when hatched remain there for several days, adhering by their posterior suckers.

CHAPTER VII

ANIMALS OF UNCERTAIN RELATIONSHIPS

IN this chapter we shall consider in a brief way a number of different groups of animals whose relationships are uncertain. Up to the present time the study of their habits, structure, and development has been of too fragmentary or unrelated a character to enable the majority of zoologists to agree upon their classification. Nevertheless, many of them are highly interesting and attractive, often very common, and in some respects they hold important positions in the animal kingdom.



FIG. 41.—A wheel-animalcule (*Rotifer*).

69. The rotifers or wheel-animalcules.—

The rotifers or wheel-animalcules are relatively small and beautiful organisms, rarely ever longer than a third of an inch, but at times so abundant that they may impart a reddish tinge to the water of the streams and ponds in which they live. At first sight they might be mistaken for one-celled animals, but the presence of a digestive tract and of reproductive elements soon dispels such a belief. Examined under the microscope, the more common forms are

seen to possess an elongated body terminating at the forward end in two disk-like expansions beset along the edges with powerful cilia. These serve to drive the animal about, or, when it remains temporarily attached

by the sticky secretion of the foot, to sweep the food-particles down into the mouth. Through the walls of the transparent body such substances are seen to pass into the stomach, where they are rapidly hammered or rasped into a pulp by the action of several teeth located there. In the absence of a circulatory system the absorbed food is conveyed by the fluid of the body-cavity, which also conveys the wastes to the delicate kidneys. Several other features of their organization are of much interest, especially to the zoologist, who believes that he gains from their simple structure some ideas of the ancestors of the modern worms, mollusks, and their allies. During the summer the rotifers lay two sizes of "summer eggs," which are remarkable for developing without fertilization. The large size give rise to females, the smaller to males, the latter appearing when the conditions commence to be unfavorable. The "winter eggs," fertilized by the males and covered with a firm shell, are able for prolonged periods to withstand freezing, drought, or transportation by the wind. The adults also are able under the same adverse conditions to surround themselves with a firm protective membrane and to exist for at least a year. Once again in the presence of moisture the shell dissolves, and in a surprisingly short space of time they emerge, apparently none the worse for the prolonged period of quiescence.

70. Gephyrea.—There is a comparatively large group of worm-like organisms, over one hundred species in all, which at present hold a rather unsettled position in the animal kingdom. Some of the more common forms (Fig. 42) living in the cracks of rocks or buried in the sand, usually in shallow tide pools along the seashore, have a spindle-shaped body terminated at one end by a circlet of tentacles which surround the mouth. On account of their external resemblance to many of the sea-cucumbers (Fig. 92), they were earlier associated in the same group; but an examination of their internal organization inclines many zoologists

to the belief that the ancestors of some of these animals were segmented worms whose present condition has arisen possibly in accordance with their sluggish habits. This view is strengthened by the fact that in a very few species

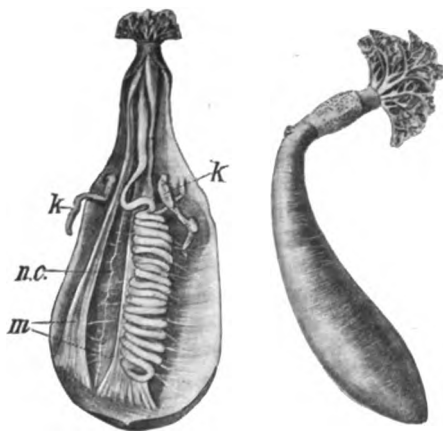


FIG. 42.—A gephyrean worm (*Dendrostoma*). Specimen on left opened to show *k*, kidney, *m*, muscle bands, and *n.c.*, nerve-cord.

the larvæ are distinctly segmented, but lose this character in becoming adult. As before mentioned, the greater number of species live in burrows in the sand or crevices in the rocks, from which they reach out and gather in large quantities of sand. As these substances

pass down the intestine the nutritive matters are digested and absorbed, while the indigestible matters are voided to the exterior. When large numbers are associated together they are doubtless important agents in modifying the character of the sea bottom, thus acting like the earth-worms and their relatives.

71. The sea-mats (Polyzoa).—The sea-mats or Polyzoa constitute a very extensive group of animals common on the rocks and plants along the seashore, and frequently seen in similar situations in fresh-water streams. A few lead lives as solitary individuals, but in the greater number of species the original single animal branches many times, giving rise to extensive colonies. In some species these extend as low encrusting sheets over the objects on which they rest; while in others the branches extend into the

surrounding medium and assume feathery shapes (Fig. 43), which often bear so close a resemblance to certain plants

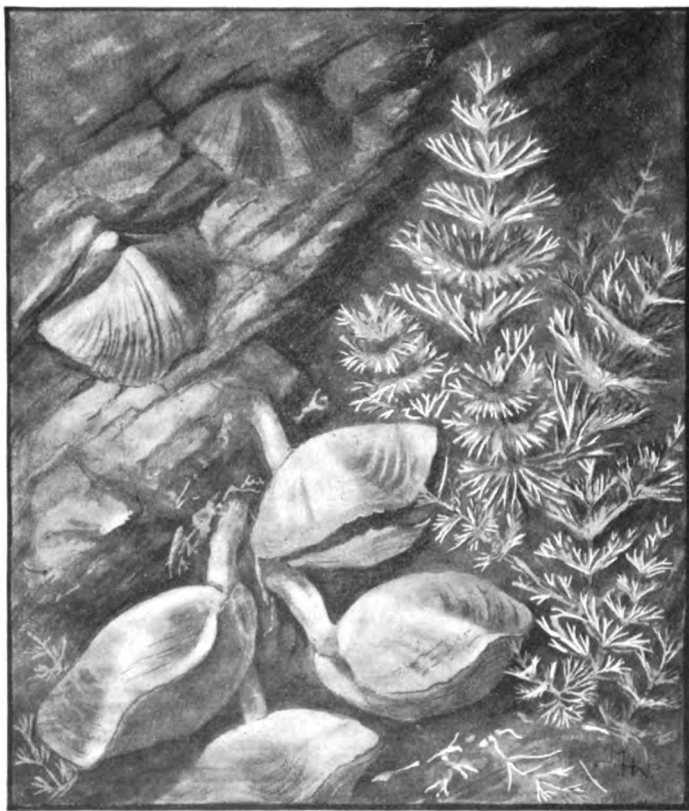


FIG. 43.—Lamp-shells or Brachiopods (on left of figure), fossil and living, and (on right) plant-like colonies of sea-mats.

that they are frequently preserved as such. What their exact position is in the animal scale it is somewhat difficult to say; but judging especially from their development, it appears probable that they are distant relatives of the segmented worms.

72. Lamp-shells or Brachiopoda.—Occasionally one may find cast on the beach or entangled in the fishermen's lines or nets a curious bivalve animal similar to the form shown in Fig. 43. These are the Brachiopods, or lamp-shells. The remains of closely related forms are often abundant as fossils in the rocks (Fig. 43). Over a thousand species have been preserved in this way, and we know that in ages past they flourished in almost incredible numbers and were scattered widely over the earth. Unable to adapt themselves to changing conditions or unable to cope with their enemies, they have gradually become extinct, until to-day scarcely more than one hundred species are known. These are often of local distribution, and many are comparatively rare.

For a long period the Brachiopods, owing to their peculiar shells, were classed together with the clams and other bivalve mollusks. The presence of a mantle also strengthened the belief; but closer examination during more recent years has shown that the shells are dorsal and ventral, and not arranged against the sides of the animal as in the clams. Another peculiar structure consists of two great spirally coiled "arms," which are comparable in a general way to greatly expanded lips. The cilia on these create, in the water currents which sweep into the mouth, the small animals and plants that serve as food. The internal organization resembles in a broad way that of the animals considered in the previous section, and it now appears that both trace their ancestry back to the early segmented worms.

73. Band or nemertean worms.—In a few cases band or nemertean worms have been discovered in damp soil or in fresh-water streams. These are commonly small and inconspicuous, and are pigmies when compared with their marine relatives, which sometimes reach a length of from fifty to eighty feet. Many of the marine species (Fig. 44) are often found on the seashore under rocks that have been exposed

by the retreating tide. They are usually highly colored with yellow, green, violet, or various shades of red, and are so twisted into tangled masses that the different parts of the body are indistinguishable. As the animal crawls about, a long thread-like appendage, the proboscis, is frequently shot out from its sheath at the forward end of the body and appears to be used as a blind man uses his stick. At other times, when small worms and other animals are encountered, the proboscis is shot out farther and with greater force, impaling the victim on a sharp terminal spine (Fig. 44). The food is now borne to the mouth, located near the base of the proboscis, is passed into the digestive tract, traversing the entire length of the body, and is farther operated on by systems of organs too complex to be considered here.

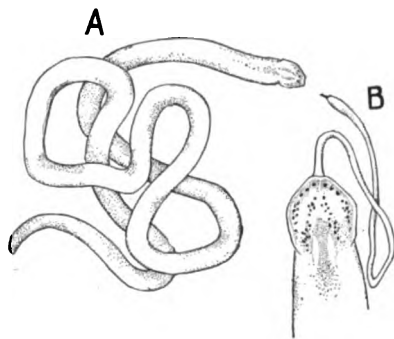


FIG. 44.—A band or nemertean worm. A, entire worm; B, head, bearing numerous eyes and spine-tipped proboscis.

CHAPTER VIII

MOLLUSKS

74. General characters.—For very many years the mollusks—that is, the clams, snails, cuttlefishes, and their allies—have been favorite objects of study largely because of the durability, grace, and coloration of the shell. The latter may be univalve, consisting of one piece, as in the snails, or bivalve, as in the clams and mussels, and may possess almost every conceivable shape, and vary in size from a grain of rice to those of the giant clam (*Tridacna*) of the East Indian seas, which sometimes weighs five hundred pounds. These external differences are but the expression of many internal modifications, which, while adapting these animals for different modes of life, are yet not sufficient to disguise a more fundamental resemblance which exists throughout the group. In some respects the mollusks show a close resemblance to the annelid worms, but, on the other hand, the body is usually more thick-set and totally devoid of any signs of segmentation. In every case the skin is soft and slimy, demanding moist haunts and usually the protection of a shell, and the body is modified along one surface to form a foot or creeping disk which serves in locomotion. The internal organization is somewhat uniform, and will admit of a general description later on. Mollusks are divided into three classes, viz.: The Lamellibranchs, embracing the clams; the Gasteropods, or snails; and the Cephalopods, or cuttlefishes, squids, and related forms.

75. Lamellibranchs (clams and mussels).—Numerous representatives of this class, such as the clams and mussels,

occur along our seacoasts or are plentifully distributed in the fresh-water streams and lakes. They are distinguished from other mollusks by a greatly compressed body, which is enclosed in a shell consisting of two pieces or *valves* locked together by a hinge along the dorsal surface. Raising one of these valves, the main part of the body may be seen to occupy almost completely the upper (dorsal) part of the shell (Fig. 45), and to be continued below into the muscular hatchet-shaped foot (*ft.*), which aids the clam in plowing its way through the sand or mud in which it lives. Arising on each side of the back of the animal and extending its entire length is a great fold of skin, which completely lines the inner surface of the corresponding valve of the shell. These are the two mantle lobes (*m*) instrumental in the formation of the shell, and enclosing between them a space containing the foot and a number of other important structures, the most conspicuous of which are the gills (*g*), consisting of two broad, thin plates attached along the sides of the animal and hanging freely into the space (mantle cavity) between the mantle and the foot. Owing to this lamella-like character of the branchia or gills the class derives its name, lamellibranch. To illustrate the relations of these various organs to one another the clam has been compared to a book, in which the shells are represented by the cover, the fly-leaves by the mantle lobes, the first two and last two pages by the gills, and the remaining leaves by the foot. In the clams, however, the halves of the mantle, like the halves of the shell, are curved, and thus enclose a space, the mantle cavity, which is partly filled by the gills and foot.

Unlike the other mollusks which usually lead active and more aggressive lives, the clams show scarcely a sign of a head and tentacles, and other sense organs are likewise absent from this region. The mouth also lacks definite organs of mastication, and as devices for catching and holding food are not developed, the food is brought to the

mouth by means of the cilia on the great triangular lips or *palps* which bound it on each side (Fig. 45, A, *p*).

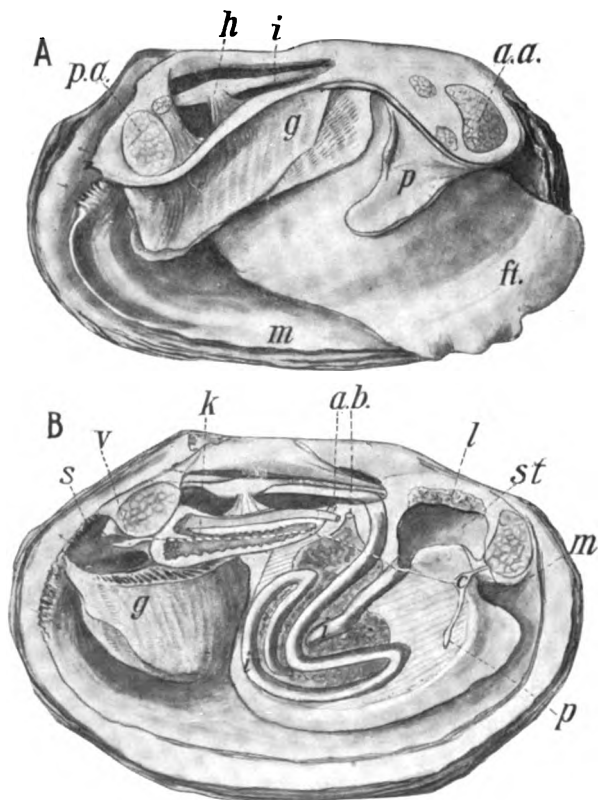


FIG. 45.—Anatomy of fresh-water clam. A, right valve of shell removed; B, dissection to show internal organs. *a*, external opening of kidney; *a.a*, the anterior muscle for closing the shell; *b*, opening of reproductive kidney; *c*, brain; *ft.*, foot; *g*, gill; *h*, heart; *i*, intestine; *k*, kidney; *l*, liver; *m*, mantle (upper fig.), mouth (lower fig.); *p*, pulp (upper fig.), foot nerves (lower fig.); *p.a.*, hinder muscle for closing the shell; *s*, space through which the water passes on leaving the body; *st*, stomach; *v*, nerves supplying viscera.

Between the halves of the shell in the hinge region is a horny pad that acts like a spring, and without any muscular effort on the part of the clam keeps the shells open.

These are also united by two great adductor muscles, located at opposite ends of the animal (Fig. 45, A, *a.a.*, *p.a.*), which in times of disturbance contract and firmly close the shell. Upon their relaxation the shell opens, the clam extends its foot, and plows its way leisurely through the mud, or remains buried, leaving only the hinder portion of its gaping shell exposed. Through this opening a current of water is continually passing in and out, owing to the action of the cilia covering the gills, and by placing a little carmine or coloring matter in the ingoing stream we may trace its course through the body. Passing in between the mantle and the foot it travels on toward the head, giving off small side streams which are continually made to enter minute openings in the gills, whence they are conducted through tubes in each gill up to a large canal at its base, where it is carried backward to the exterior. In this process oxygen gas is supplied to the number of blood-vessels traversing the gills, and at the same time considerable quantities of minute organisms and organic *débris* are hurried forward toward the head, where they encounter the whirlpools made by the cilia on the lips and are rapidly whisked down into the mouth and swallowed.

75. Rock- and wood-boring clams.—Other similar forms are rendered even more secure through their ability to bore in solid rock. In the common Piddock, for example (Fig. 46), the shell is beset with teeth like a rasp, which gradually enlarge the cavity as the animal grows, until it becomes a prisoner with no means of communication with the exterior save the small opening through which the siphons project. This is also the case with the *Teredo*, frequently called the shipworm, which swims about for some time during early life and then, about the size of a small pinhead, settles down upon the timbers of wharves or unsheathed ships, into which it rapidly tunnels. Throughout life its excavation is extended sometimes to a distance of two to three feet, and imprisoned yet safe at

the bottom of its burrow, it extends its slender siphons up the tube and out of the entrance for its food supply. Often hundreds of individuals enter the same piece of wood, which becomes thoroughly riddled within a short

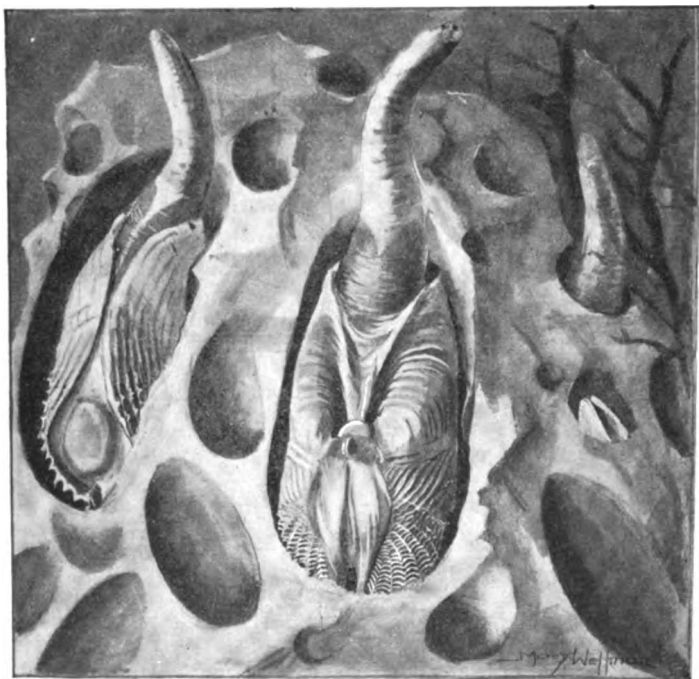


FIG. 46.—The piddock (*Zirphæa crispata*), a rock-boring mollusk. Natural size, from life.

time, and though giving no outward sign of weakness may collapse with its own weight. Incalculable damage is thus rendered to the shipping interests, and in consequence much has been done to check their ravages, but they are far from being completely overcome.

76. Other stationary species.—A large number of other species, while small and inconspicuous, are also free to

move about, but as they become larger they lose this ability either wholly or periodically. In the edible mussels (*Mytilus*, Fig. 47), for example, which are associated in great numbers on the rocks along our coasts, the foot early becomes long and slender and capable of reaching out a considerable distance from the shell to attach threads (byssus), which it spins, to foreign objects. These are remarkably strong, and when several have been spun it becomes a matter of much difficulty to dislodge them. After remaining anchored in one situation for a while the mussel may vol-

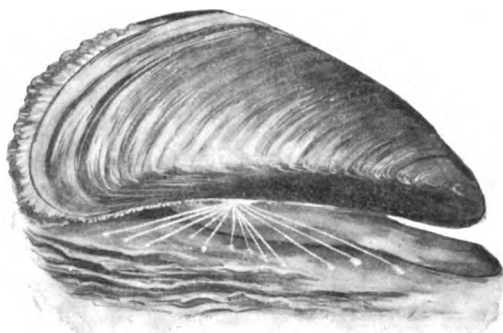


FIG. 47.—The edible mussel (*Mytilus edulis*), showing the threads by which it is attached. Natural size, from life.

untarily free itself, and in a labored fashion move to some other more favorable spot where it again becomes attached, but there are numerous species, such as “fan shells” (*Pinna*), scallops, *Anomia*, and a few fresh-water forms, where the union is permanent.

Finally, in the oysters, some of the scallops, and a number of less familiar forms, the young in very early life drop down upon some foreign object to which the shell soon becomes firmly attached, and in this same spot they pass the remainder of their lives. The oyster usually falls upon the left half of its shell, which becomes deep and capacious enough to contain the body, while the smaller right valve

acts as a lid. As locomotion is out of the question, the foot never develops, and the shell is held by only one adductor muscle, whose point of attachment in the oyster is indicated by a brown scar in the interior of the shell.

77. Internal organization.—It is thus seen that the external features of the clam are variously modified, according to the life of the animal, but the internal organization is much more uniform. In nearly every species the food consists of floating organisms, which are driven by the palps into the mouth and on to the simple stomach, where it is subjected to the solvent action of the fluids from the liver (Fig. 45, B, *l*) before entering the intestine. This latter structure is usually of considerable length, and in the active species extends down into the foot, and it is also peculiar in passing through the ventricle of the heart. Traversing the intestine the nutritive portion of the food is absorbed, and is conveyed over the body by a circulatory system more highly developed than in the higher worms. On the dorsal side of the clam, in a spacious pericardial chamber, the large heart is situated (Fig. 45, *h*), consisting of a median highly muscular ventricle surrounding the intestine and of two thin auricles, one on either side. From the former, two arteries with their numerous branches convey the blood to all parts of the body, where it accumulates, not in capillaries and veins, but in spaces or *sinuses* among the muscles and various organs, constituting a somewhat indefinite system of channels which lead to the gills and kidneys. In these organs the blood delivers up the waste which it has accumulated on its journey, and absorbing a supply of oxygen, it flows into the great auricles, which in turn pass it into the ventricle to circulate once more throughout the body.

The excretory apparatus, consisting usually of two kidneys, of which one may degenerate in many snails, bears a close resemblance to that of the annelids. In the clam, for instance, each consists of a bent tube symmetrically ar-

ranged on each side of the body (Fig. 45, B, *k*), and the inner ends (*a*), corresponding to the ciliated funnel of the annelid kidney, open into the pericardial cavity. The walls are continually active in extracting wastes from the blood supplied to them, and these, together with the substances swept out from the pericardial cavity, traverse the tube and are carried to the exterior. In other mollusks the kidney may be more compact, or greatly elongated, or otherwise peculiar, but in reality they bear a close resemblance to those of the clam.

78. Nervous system.—The nervous system, like the excretory, differs considerably in different mollusks, yet the resemblances are fairly close throughout. In the clam the cerebral ganglia corresponding to the “brain” in annelids is located at either side, or above the mouth, and from it several nerves arise, the larger passing downward to two pedal ganglia (*p*) embedded in the foot and to the visceral ganglia (*v*) far back in the body (Fig. 45, B). These nerve centers continually send out impulses which regulate the various activities of the body and also receive impressions from without. These come chiefly through the sense of touch, for in the clams the other senses are usually either feebly developed or altogether absent.

79. Development.—In the mollusca new individuals always arise from eggs, which are commonly deposited in the water and there undergo development. In the fresh-water clams the reproductive organ is usually situated in the foot (Fig. 45), while in the oyster and similar inactive species it is attached to the large adductor muscle. In these latter, and in many other marine forms, the eggs are shed directly into the sea, where they are left to undergo their development buffeted by winds and waves and subject to the attack of numerous enemies. Under such circumstances the chances of survival are slight, and for this reason eggs are laid in vast numbers, which have been variously estimated for the oyster, for example, from two to forty million. Develop-

ment proceeds at first much as in the sponge, but soon the shell, foot, gills, and various other molluscan structures put in an appearance, and the few surviving young which have been free-swimming now settle down in some favorable spot, and attach themselves or burrow according to their habit.

80. Life history of fresh-water clams.—The life history of our common fresh-water clams is perhaps one of the most remarkable known among mollusks. The parent stores the eggs, as soon as they are laid, in the outer gill plate, and there, well protected, they undergo the first stages of their development, which results in the formation of minute young enclosed in a bivalve shell beset with teeth. These are often readily obtained, sometimes as they are escaping from the parent, and when examined under the microscope are seen to rapidly open and close their shells in a snapping fashion when in the least disturbed. In a state of nature this latter movement may result in attaching the young to the fins or gills of some passing fish, which is necessary to its further development. Within a short time it becomes completely embedded in the flesh of its host, from which, as a parasite, it draws its nourishment, and during the next few weeks undergoes a wonderful series of transformations resulting in a small mussel, which breaks its way through the thin skin of the fish and drops to the bottom.

81. The gasteropods.—The gasteropods, including snails, slugs, limpets, and a host of related forms, fully twenty thousand different species in all, are found in most of our fresh-water streams and lakes and in moist situations on land, while great numbers live along the seashore and at various depths in the ocean, even down as far as three miles. Examining any of them carefully we find many of the same organs as in the clams, but curiously changed and adapted for a very different and usually active life. In our common land snails (Fig. 48), which we may well examine before passing on to a general survey of the group, the first

striking peculiarity is in the univalve shell, with numerous whorls, into which the animal may at any time withdraw completely. Ordinarily this is carried on the back of the spindle-shaped body, which is fashioned beneath into a great



FIG. 48.—The slug (*Ariolimax*) and common snail (*Helix*). From life.

flat sole or creeping surface that bears on its forward border a wide opening through which mucus is continually issuing to enable the snail to slip along more readily. Slime also exudes on other points on the surface of the body and affords a valuable protection against excessive heat and drought.

Unlike the clams, the forward end of the body is developed into a well-marked head bearing the mouth and a complicated mechanism for gathering and masticating food, together with two pairs of tentacles, one of which carries the eyes. On the right side of the animal, some distance behind the head, is the opening of the little sac-like mantle cavity (Fig. 48) which contains the respiratory organs, and into which the alimentary canal and the kidneys pour their wastes. The relation of these organs to the mantle cavity is the same as in the clams, though the cavities differ much in size and position.

82. Other snails. The shell.—Extending our acquaintance to other species of snails, we find the same general plan of body, although somewhat obscured at times by

many modifications. A foot is generally present, also a more or less well-developed head, and the body is usually surrounded by a shell which varies widely in shape and size in different species. In the common limpets the early coiled shell is transformed into an uncoiled cap-like one, and in the keyhole limpets is perforated at its summit. The

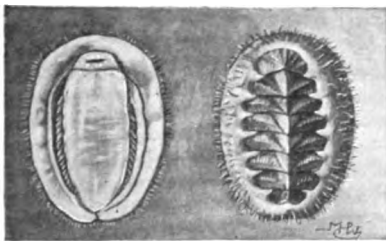


FIG. 49.—The chiton, armadillo-snail or sea-cradle. The left-hand figure shows mouth in center of proboscis, the broad foot on each side of which are numerous small gills. The right-hand figure shows the mantle and shell, composed of eight plates. From life, one-half natural size.

chitons or armadillo-snails (Fig. 49), often found associated with the limpets, carry a most peculiar shell consisting of eight plates, which enables the animal to roll up like an armadillo when disturbed. A shell is by no means a necessity, however, for in many species, such as the beautiful naked snails or Nudibranchs (Fig.

50) common along our coasts, it may be entirely absent, or, as in the ordinary slugs, reduced to a small scale embedded in the skin.

83. **Respiration.**—A considerable quantity of oxygen is absorbed through the skin, as in all mollusks, but the chief part of the process is usually taken by the plume-like gills, one or two in number, which are located in the mantle cavity. In the chitons (Fig. 49) the number of gills is greater, amounting in some species to over a hundred, while in the Nudibranchs (Fig. 50) gills are absent, their places being taken by more or less feathery expansions of the skin on the dorsal surface.

Many of the gasteropods left exposed on the rocks by a retreating tide retain water in the mantle cavity, from which they extract the oxygen until submerged again.

Others breathe by means of gills while under water, and by the surface of the body and the moist walls of the mantle

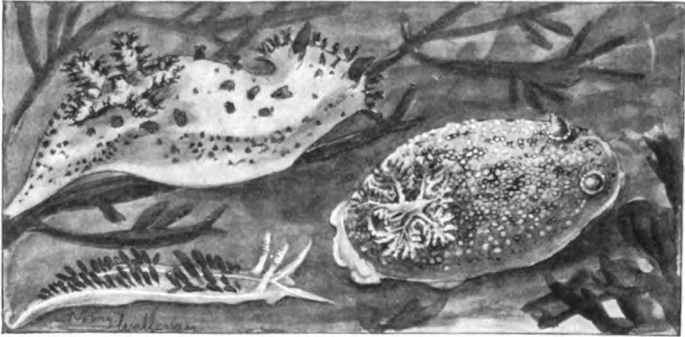


FIG. 50.—Three different species of naked marine snails or Nudibranchs. Natural size, from life.

cavity when exposed. In some of the small *Littorinas*, attached so far from the sea as to be only occasionally washed by the surf this latter method may prevail for days together—in fact they live better out of water than in it. It is not difficult to imagine that such forms, keeping in moist places, might wander far from the sea, and, losing their gills, become adapted to a terrestrial life. It is believed that in past times this has actually occurred, and that our land forms trace their descent from aquatic ancestors. To-day they breathe by a lung—that is, they take oxygen through the walls of the mantle cavity, as the slug may be seen to do, though in some species traces of the old gill yet remain.

84. Food and digestive system.—Many mollusks live upon seaweeds, and the greater number of terrestrial forms are fond of garden vegetables or certain kinds of lichens, but, on the other hand, the latter, together with a large number of marine snails, are carnivorous. In all cases the food requires to be masticated, and, unlike the clams, the mouth is usually provided with horny jaws, and an additional

masticatory apparatus which consists of a kind of tongue with eight to forty thousand minute teeth in our land forms (Fig. 51), while in certain marine snails they are beyond computation. With the licking motion of the tongue this rasp tears the food into shreds before it is swallowed, and in the whelks or borers it serves to wear a circular hole through the shells of other mollusks, which are thus killed and devoured.

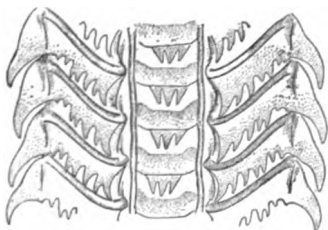


FIG. 51.—A small portion of the radula or tongue-rasp of a snail (*Sycotypus*).

This latter process is facilitated by the secretion of the salivary glands, which has a softening effect upon the shell. Ordinarily the saliva of snails exercises some digestive action.

In the stomach of some snails are teeth or horny ridges which also are instrumental in crushing the food, and in numerous minor respects peculiarities exist in different species according to the nature of the food; but in its general features the digestive tract is similar to that of the clams.

The processes of circulation and excretion are also carried on by means of systems which show a certain resemblance to those of the clams. As might be expected, certain differences exist, sometimes very great, but they are of too technical a nature to concern us further.

85. Sense-organs of lamellibranchs and gasteropoda.—The eyes of mollusks differ widely in their structure and the position they occupy in the body. In our common land snails two pairs of tentacles are borne on the head, the lower acting as feelers, while each of the upper ones bears on its extremity the eye, appearing as a minute black dot (Fig. 48). In this same position the eyes of many marine snails occur, but there are numerous species in which there are other accessory eyes. In many of the

limpets, for instance, there are numbers of additional eyes carried on the mantle edge just under the eaves of the shell, and forming a row completely encircling the body. (In the scallops there are two rows of brilliantly colored eyes, set like jewels on the edges of the mantle just within the halves of the shell.) In the chitons the eyes of the head disappear by the time the animal attains maturity, and in some species at least their place appears to be taken by great numbers of eyes, sometimes thousands, which are embedded in the shells. On the other hand, eyes are completely absent in certain species of burrowing snails and in several living in the gloomy depths of the sea far from the surface; they appear to be absent also from fresh-water clams; but the fact that certain species close their shell when a shadow falls upon them, leads to the belief that while actual eyes are not present the skin is extremely sensitive to light. This is also the case with many snails.

86. Smell.—Since the sense of sight is generally undeveloped in the mollusks, they rely chiefly upon touch and smell for recognizing the presence of enemies and food. Tentacles upon the head and other parts of the body, and a skin abundantly supplied with nerves, show them to possess a high degree of sensibility; but in the greater number of species the sense of smell is of chief importance. Many experiments show that tainted meat and strongly scented vegetables concealed from sight and several feet distant from many of our land and sea mollusks will attract them at once. In these forms the sense of smell appears to be located on the tentacles, but additional organs, possibly of smell, are located on various portions of the body, usually in the neighborhood of the gills.

87. Taste and hearing.—Several mollusks appear to be almost omnivorous, but others are decidedly particular in their choice of food, which leads us to suspect that they possess to some extent the sense of taste. Nerves supplying the base of the mouth have also been detected, which

may be those of taste; but experiments along the line are difficult to perform, and our knowledge of this subject is far from complete. The same is true of hearing. Certain organs, interpreted as ears and located in the foot, have the form of two hollow sacs, containing one or more solid particles of sand or lime, whose jarrings, when effected by sonorous bodies, may result in hearing. On the other hand, it is held by some that they, like the semicircular canals of higher animals, may regulate the muscular movements which enable the animal to keep its balance.

88. Egg-laying habits and development.—The egg-laying habits of the gasteropods differ almost as widely as their haunts. The terrestrial forms lay comparatively few eggs, ranging in size from small shot to a pigeon's egg in some of the tropical species. These are buried in hollows in the ground or under sticks and stones, and after a few weeks hatch out young snails having the form of the adult. The same is also true of most of the fresh-water snails, which lay relatively smaller eggs embedded in a gelatinous mass frequently found attached to sticks and leaves, or on the walls of aquaria in which they are confined. Many marine species construct capsules of the most varied patterns which they attach to different objects, and in these the young are protected until they hatch. In the limpets and many of the chitons the eggs are laid by thousands directly in the water, and after a short time develop into free-swimming young, differing considerably from the parent in appearance. Those escaping the ravages of numerous enemies finally settle down in a favorable situation and gradually assume the form of the adult.

89. Age, enemies, and means of defense of lamellibranchs and gasteropoda.—How much time is consumed by the young in growing up, and the length of time they live, are questions generally unsettled. It is said that the oyster requires five years to attain maturity, and lives ten years; the fresh-water clam develops in five years, and some species live from

twelve to thirty years; and the average length of life of the snail appears to be from two to five years. Certain it is that mollusks have numerous enemies besides man which prevent multitudes from living lives of normal length. Birds, fishes, frogs, and starfishes beset them continually, and many fall a prey to the ravages of internal parasites or to other mollusks. Under ordinary circumstances the shell is sufficient protection, and the spines disposed on the surface in many species render the occupant still less liable to attack. Many snails carry on the foot a horny or calcareous plate known as the operculum, which closes the entrance of the shell like a door against intruders. Certain noxious secretions poured out from the skin also serve as a means of defense, and many Nudibranchs (Fig. 50) bear nettle-cells on the processes of the body, which probably render them distasteful to many animals. Finally, there are numerous clams, mussels, snails, and slugs whose colors harmonize so closely with their surroundings that they almost completely baffle detection, and enable them to lead as successful a life as those provided with special organs of defense.

90. Cephalopoda.—The animals belonging to this class, such as the squids and cuttlefishes (Fig. 52), are by far the most highly developed mollusks: They are of great strength, capable of very rapid movements, and several species are many times the largest invertebrates. In almost every case there is a well-defined head bearing remarkably perfect eyes, and also a circle of powerful arms provided with numerous suckers which aid in the capture of food (Fig. 52). Posteriorly the body is developed into a pointed or rounded visceral mass which to a certain extent is free from the head, giving rise to a well-marked neck. Some forms, such as the squids (Fig. 52, upper figure), are provided with fins which drive the animal forward, but in common with other cephalopods they are capable of a very rapid backward motion. By muscular movements water is taken

into the large mantle cavity within the body, a set of valves prevents its exit through the same channels, and upon a vigorous contraction of the body walls the water is forced out rapidly through the small opening of the funnel, which

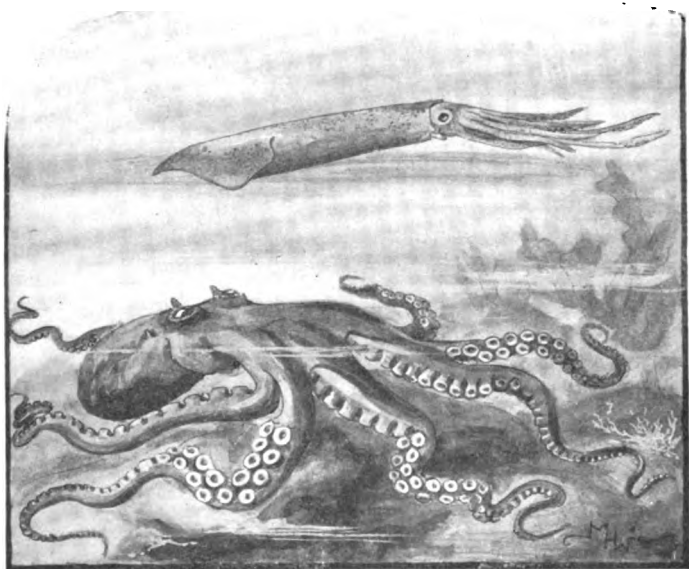


FIG. 52.—Cephalopods. Lower figure, the devil-fish or octopus (*Octopus punctatus*). The upper figure represents the squid (*Loligo pealii*) swimming backward by driving a stream of water through the small tube slightly beneath the eyes. From life, one-third natural size.

drives the animal backward after the fashion of an exploding sky-rocket. In this way they usually escape the fishes and whales that prey upon them, but an additional device has been provided in the form of a sac within the body, whose inky contents may be liberated in such quantity as to cloud the water for a considerable distance, and thus enable them to slip away unseen into some place of safety.

Most of the cephalopods are further protected by their ability to assume, like the chameleon, the color of the object

upon which they rest. In the skin are embedded multitudes of small spherical sacs filled with pigments of various colors, chiefly shades of red, brown, and blue, each sac being connected with a nerve and a series of delicate muscles. If the animal settles upon a red surface, for example, a nerve impulse is sent to each of the hundreds of color sacs of corresponding shade, causing the muscles to contract and flatten the bag like a coin, and thus exposing a far greater surface than before, they give the animal a reddish hue. In the twinkling of an eye they may completely change to another tint, or present a mottled look, and some may even throw the surface of the skin into numerous small projections that make the animal appear part of the rock upon which it rests. These devices not only serve for protection, but they also aid in enabling these mollusks to steal upon their prey, chiefly fishes, which they destroy in great numbers with lionlike ferocity.

The devil-fishes and a number of other species are usually found creeping along the sea bottom, generally near shore, and are solitary in their habits, while the squids remain near the surface and frequently travel in great companies, sometimes numbering hundreds of thousands. In size they usually range from a few inches to a foot or two in length, but a few devil-fishes and squids attain a greater size, some of the latter reaching the enormous length of from forty to sixty feet. There are many stories of their great strength and of their voluntarily attacking people and even overturning boats, but the latter are in almost every case sailors' yarns.

In their external organization the cephalopods have little to remind one of any of the preceding mollusks, and their internal structure shows only a distant resemblance. In the Octopi (Fig. 52) the shell is lacking; in the squid it is called the pen, and consists of a horn-like substance without any lime deposit; in the cuttlefishes it is spongy and plate-like, and is a familiar object in the shops; and, finally,

in the nautilus it is coiled and of considerable size, and, unlike that of any other cephalopod, it is carried on the outside of the animal. Interiorly it is divided by a number of partitions into chambers, the last one of which is occupied by the animal.

The alimentary canal shows some resemblance to that of other mollusks, but, as in the case of the other systems of the body, it possesses a far higher state of development. The mouth is situated in the center of a circle of arms, which in reality are modified portions of the foot, and is furnished with two parrot-like jaws. From this point the esophagus leads back into the body mass to the stomach, which with the liver and intestine are sufficiently like those of the clam and snail to require no further comment.

Respiration is effected by the skin to a certain extent, but chiefly by two gills (four in the nautilus), and the circulatory system, which conveys the blood to and from these organs and over the body with its complex heart, arteries, capillaries, and veins, is more highly developed than in any other invertebrate.

As might be expected in animals with so great sagacity and cunning, the nervous system and the sense-organs reach a degree of development but little short of what we find in some of the vertebrates. The chief part of the nervous system is located in the head, protected by a cartilaginous skull, a very rare structure among invertebrates; and while the different ganglia may be recognized in a general way and be found to correspond to a certain extent to those of foregoing mollusks, they are so largely developed and massed together that it is impossible at present to understand them fully. From this point nerves pass to all regions of the body, to the powerful muscles, the viscera, and the organs of special sense, controlling the complex mechanism in all its workings.

There is no doubt that the cephalopods see distinctly for considerable distances, and a careful examination of

the eye of the squids and cuttlefishes has shown them to be remarkably complex and in many respects to be constructed upon much the same plan as those of the vertebrates. As to the other senses not so much is known, but undoubtedly many species of cephalopods are possessed of a shrewdness and cunning not shared by any other invertebrates, save some of the insects and spiders, and are vastly more highly organized than their molluscan relatives.

91. How species originate.—We have now examined a considerable portion of the animal kingdom, tracing its members from their simplest beginnings as single cells, through the formation of colonial types, and up through the sponges, cœlenterates, worms, and mollusks. It is important once more to note that they all perform the functions concerned in nutrition and reproduction, and only these. The differences which exist are those of structure. The *Hydra* and the clam, for example, perform the same duties, but their bodily apparatus differs widely, and the completeness and perfection of the work varies accordingly. The more the work to be performed by an organism is divided up among especially adapted organs, so that each of the latter has, as far as possible, only one thing to do, the higher is the organism.

As stated earlier in the account, it is believed that the more complex animals arose from the simpler; that if we could trace the history of any of the great groups back toward their first beginnings, we would find them all to have originated from one ancestral form, that in turn owes its descent from yet simpler forms.

Let us see something of how this has come about. We all know that vast numbers of young are born into this world which never come to maturity. It is said that if all the young of the codfish were to live their allotted time, it would be less than fifteen years before the sea would become literally packed with them. Numerous enemies,

the lack of food, and other agencies annihilate the larger part. We also know that no two offspring are exactly alike. They exhibit individual differences. One bird may have a larger bill than another of the same brood which excels in length of wing. As noted above, all the offspring will not attain maturity. Those best adapted to their surroundings will have the best chances of survival. The increased length of bill or wing may be slight, but it may be just this amount which enables the bird to probe deeper or fly farther and thus secure the requisite amount of food. A premium is placed on length of wing or bill generation after generation, with the result that a long-billed species arises distinct from the long-winged which trace their ancestry back to the same parents. It is the same principle which enables the breeder to increase the swiftness of the race-horse and the strength of the draft-horse, or the gardener to develop from the wild rose the great number of widely different varieties. In the same way other slight peculiarities over very many generations may enable other forms to gradually adapt themselves to still different modes of life. Thus vast numbers of organisms gradually become modified in form and complexity, and are adapted to lives which insure them a comparative degree of safety and less competition with other species.

The above account serves solely for purposes of illustration. No kind of bird has originated in just that way, but as the essential force in all change of form we have the necessity of adaptation of the individual to its surroundings, the death of those who can not be adapted, and the inheritance of the advantage of the parent by its progeny, enabling these in turn to survive and to multiply their own kind.

CHAPTER IX

ARTHROPODS. CLASS CRUSTACEA

92. General characters.—In the Arthropods, that is, the crabs, lobsters, shrimps, insects, spiders, and a vast host of related forms, the body is bilaterally symmetrical, and is composed of a number of segments arranged in a series, as in the earthworm and other annelids. A hornlike cuticle, sometimes called the shell, bounds the external surface—in early life thin and delicate, but later relatively thick, and often further strengthened by lime salts. Along the line between the segments this coat of mail remains thin and forms a flexible joint. Appendages also are borne on each segment, not comparatively short and fleshy outgrowths like the lateral appendages of many of the worms, but usually long and jointed (hence the name Arthropod, meaning jointed foot), and variously modified for many different uses.

93. Classification.—The species belonging to this group outnumber the remainder of the animal kingdom. Their haunts also are most diverse. Some are adapted for lives in the sea and fresh water, others for widely different situations on land, and a great number are constructed for a life on the wing. A certain resemblance exists among them all, but the modifications which fit them for their different habitats are also profound, and have resulted in the division of the Arthropods into five classes. The first class (*Crustacea*) contains the crayfish, crabs, etc.; the second (*Onychophora*) includes the curious worm-like peripatus (Fig.

66); the third (*Myriapoda*, meaning myriad-footed) embraces the centipeds and "thousand-legs"; the fourth (*Insecta*) contains the insects; and the fifth (*Arachnida*) includes the scorpions, spiders, and mites.

94. The Crustacea.—The number of species of crustaceans is estimated to be about ten thousand, and while the greater number of these are marine, many are found in fresh water and a few occur on land. In size they range from almost microscopic forms to the giant crabs and lobsters. They differ also in shape to a remarkable degree, but at the same time there is a decided resemblance throughout the group, except in those species which have become modified by a parasitic habit. The characteristic external skeleton is invariably present, and gives evidence of the deep internal segmentation of the body. In the simple Crustacea this is very apparent, but in the higher forms it is usually more or less obscured, owing to the fusion of some of the different segments, especially those of the head, as in the crayfish (Fig. 59).

The class of the Crustacea is subdivided into two subclasses (*Entomostraca* and *Malacostraca*), the first containing the fairy-shrimps (*Branchipus*, Fig. 53) and their allies, the copepods (such as Fig. 54), the barnacles (Fig. 55), and a number of other species. In their organization all are comparatively simple, usually small, and the appendages show relatively little specialization. The other subclass contains the more highly developed and usually large-sized Crustacea, among which are the shrimps, crayfishes, lobsters, crabs, and a number of other forms.

95. Some simple Crustacea.—While the members of the first subclass are minute and inconspicuous, several species are often remarkably abundant in our small fresh-water pools. Among these is the beautifully colored fairy-shrimp (*Branchipus*, Fig. 53), with greatly elongated body and leaf-like appendages, whose relatively simple character leads the zoologist to think that they are among the simplest

Crustacea, and in several points resemble the ancestral form from which all the modern species have descended. Some nearly related forms are provided with a great fold of the body-wall, which may almost completely conceal the animal from above, or it may be formed like a bivalve clam-shell, within which the entire body may be withdrawn. This

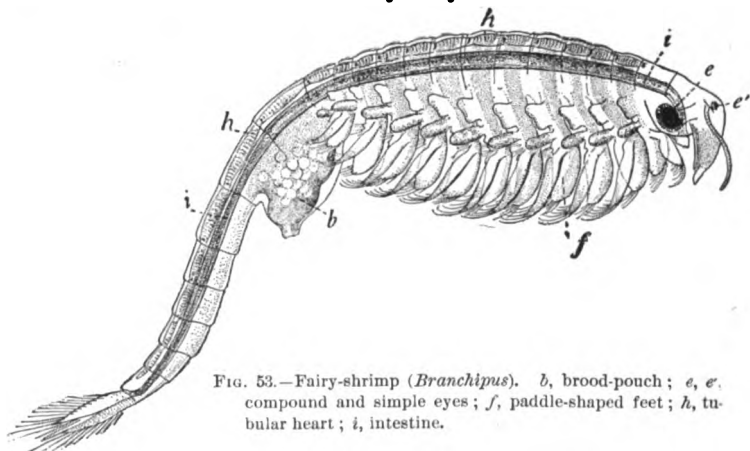


FIG. 53.—Fairy-shrimp (*Branchipus*). *b*, brood-pouch; *e*, *e'*, compound and simple eyes; *f*, paddle-shaped feet; *h*, tubular heart; *i*, intestine.

latter character is also found in the water-fleas (*Daphnia*), very much smaller forms, and sometimes occurring in millions on the bottoms of our ponds and marshes. They are readily distinguished from the fairy-shrimp by the shortness of the body, the small number of appendages, and by their habit of using their antennæ as swimming organs, which gives to their locomotion a jerky, awkward character.

96. **Cyclops and relatives.**—*Cyclops* (Fig. 54), the representative of a number of lowly forms belonging to the order of Copepods, is one of the commonest fresh-water Crustacea. The forward segments of the spindle-shaped body are covered by a large shield or carapace, the feet are few in number, and, like its fabled namesake, it bears an eye in the center of the forehead. Nearly related species are also remarkably abundant at the surface of the sea, at times occur-

ring in such vast numbers that they impart a reddish tinge to the water over wide areas, and at night are largely re-

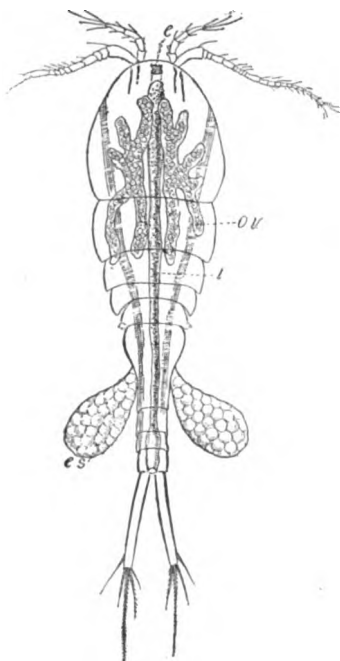


FIG. 54.—Cyclops. *e. s.*, eggs; *i.*, intestine; *or.*, reproductive organ.

sponsible for its phosphorescence. Many others are parasitic in their habits, and scarcely a salt-water fish exists but that at one time or another suffers from their attacks. On the other hand, many fresh- and salt-water fishes depend upon the free-swimming forms for food, and hence, from an economic point of view, they are highly important organisms.

97. Barnacles. — The parasitic habit and the lack of locomotion has also produced marvelous changes among the barnacles, so great that originally they were placed among the mol-

lusk; and as with the parasitic copepods, their true position was only known after their life-history had been determined. In the goose-barnacles* the body, attached by a fleshy stalk to foreign objects, is enclosed by a tough membrane, corresponding to the carapace of other Crustacea, in which are embedded five calcareous plates. This

* So called because of the belief, which existed for three hundred years prior to the present century, that when mature these animals give birth to geese.

is open along one side, and allows the feather-like feet to project and produce currents in the surrounding water which brings food within reach. In the acorn-barnacles (Fig. 55) the stalk is absent, and the body, though possess-

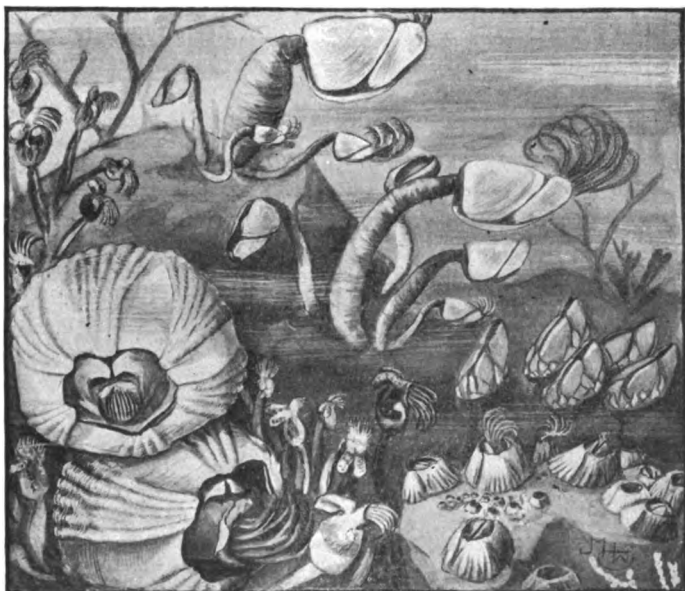


FIG. 55.—Barnacles. Acorn-barnacles chiefly in lower part of figure; goose-barnacles above. Natural size.

ing the same general character as the goose-barnacles, is shorter, and enclosed in a strong palisade consisting of six calcareous plates.

The larger number of barnacles attach themselves to the supports of wharves, the hulls of ships, floating timbers, the rocks from the shore-line down to considerable depth, and a few species occur on the skin of sharks and whales. On the other hand, there are several species which are parasitic, and in accordance with this mode of life exhibit various degrees of degeneration. In the most extreme

cases (*Sacculina*) the sac-like body, attached to the abdomen of crabs, is entirely devoid of appendages and any signs of segmentation. A root-like system of delicate filaments extends from the exposed part of the animal into the host and absorbs the necessary nutriment. The mouth and alimentary canal are accordingly absent—in fact, the body contains little but the reproductive organs and a very simple nervous system.

98. **Structure.**—In the internal organization of these smaller crustaceans many differences may be noted, though they are usually less profound than the external. Ordinarily the alimentary canal is a straight tube passing through the body, and is provided with a pouch-like stomach, and a more or less clearly defined liver. In all, except the parasitic species, the external mouth-appendages masticate the food, and in a very few of the above-described groups it may be further ground between the horny ridges on the stomach-walls. After this preliminary treatment it is subjected to the action of the digestive juices, and when liquefied is absorbed into the body. Here it is circulated by a blood-system of widely different character. In many cases definite arteries and veins are absent. The blood courses through the body in the spaces between the different organs propelled by the beating of the heart, which it is made to traverse. In *Cyclops* (Fig. 54) even the heart is absent, and the blood is made to circulate by contractions of the intestine. In most of these smaller Crustacea considerable oxygen is absorbed through the body-wall; but in several species, for example, the fairy-shrimp (Fig. 53), special gills are developed on the appendages of the body.

99. **Multiplication.**—Among the Crustacea thus far considered the males are usually readily recognized owing to their small size. The females also are usually provided with brood-pouches in which the developing eggs are protected. In almost every case the young are born in the

form of minute larvæ, provided with three pairs of appendages, a median eye (Fig. 56), and a firm external skeleton or cuticle. This latter prevents the continuous growth of the larvæ or *nauplius*, and every few days it is thrown off, and while the new one is forming the body enlarges. During this time new appendages are developed, so that after each moult the young crustacean emerges less like its former self and more and more like its parents. In the barnacles, after several moults have taken place, the young become permanently attached by means of their first antennæ, their thoracic feet change into feathery appendages, and several other changes occur. In some of the parasitic barnacles (*Sacculina*) the larva attaches itself to a crab, throws off its various appendages, and, after other great degenerative changes, enters its host. For a time, therefore, their development is toward greater complexity, but the later stages constitute a *retrograde metamorphosis*.

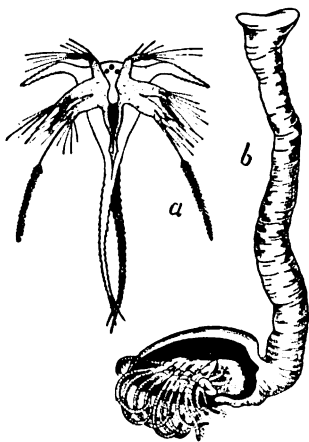


FIG. 56.—Development of a barnacle (*Lepas*). a, larva ; b, adult.

100. **More complex types.**—The larger, more useful, and usually more familiar Crustacea belong to the second division (subclass Malacostraca). It comprises such animals as the shrimps, crayfish, lobsters, crabs, and a number of other forms which are at once distinguished from the preceding by the constant number of segments composing the body. Of these, five constitute the head, eight the thorax, and seven the abdomen. The head segments are always fused together, and with them one or more thoracic segments unite to form a more or less complete cephalothorax. Also,

some of the head segments give rise to a great fold of the body-wall, the carapace, which extends backward and covers all or a part of the thorax, with which it may firmly unite, as in the crayfish. The appendages are usually highly specialized, and are made to perform a variety of functions.

101. **The shrimps.**—Among the simplest of these are the opossum-shrimps (Fig. 57) and their relatives, small trans-

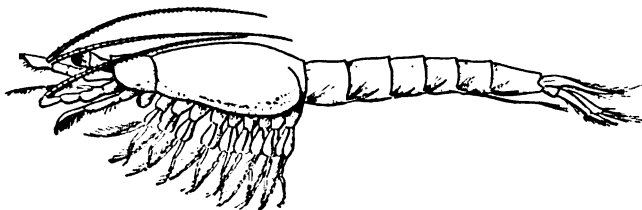


FIG. 57.—The opossum-shrimp (*Mysis americana*).

parent creatures often seen swimming in great numbers at the surface of the sea or hiding among the seaweeds along the shore. In general appearance they resemble crayfishes or prawns, but are readily distinguished by the two-branched thoracic feet. This “split-foot” character also occurs among many of the preceding Crustacea, and is generally a badge of low organization, tending to disappear in the more highly organized forms. In this and other respects the shrimps are especially interesting in their relation to the preceding Crustacea, and in the fact that they may closely resemble the ancestors of the modern prawns (Fig. 58), lobsters, crayfishes, and crabs.

102. **Crayfishes and lobsters.**—The last-mentioned species and their allies, usually large and familiar forms, constitute a group known as the decapods (meaning ten feet), referring to the number of thoracic feet. Among the members of this division probably none are more familiar than the crayfishes, which occur in most of the larger rivers and their tributaries throughout the United States and Europe. It is their habit to remain concealed in crevices of rocks

or in the mouths of the burrows which they excavate, and from which they rush upon the small fish, the larvæ of

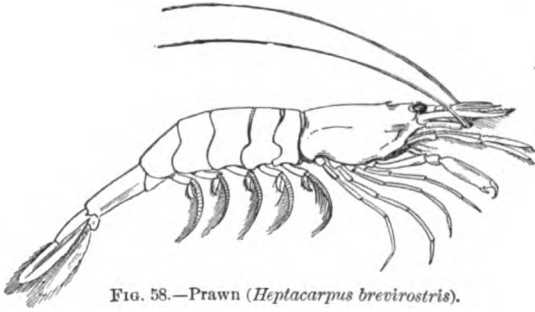


FIG. 58.—Prawn (*Heptacarpus brevirostris*).

many animals, and other equally defenseless creatures which constitute their bill of fare. In turn they are eagerly sought by certain birds and four-footed animals, and, especially in France, are extensively used for food by man.

Closely related to the crayfishes and differing but little from them structurally are the lobsters. In this country they are confined to the rocky coasts from New Jersey to Labrador, living upon fish, fresh or otherwise, various invertebrates, and occasionally seaweeds. Far more than the crayfish, the lobster is in demand as an article of food. By the aid of nets or various traps

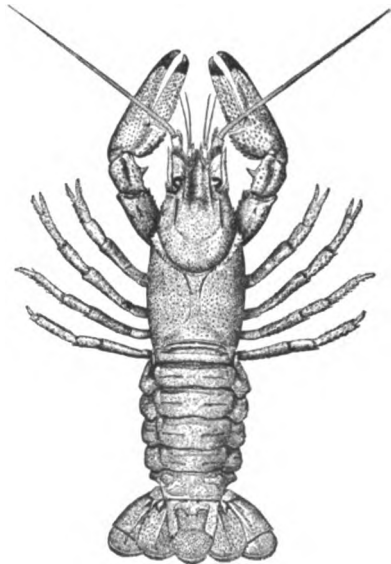


FIG. 59.—The crayfish (*Astacus*).

millions are caught each year, and to such an extent has their destruction proceeded that in many places they are well-nigh exterminated. At the present time, however, legislation, numerous hatcheries, and a careful study of their life habits is doing much to better matters and incidentally to put us in possession of many interesting zoological facts along this line, some of which will be mentioned later. Frequently the prawns, especially the larger ones, and a spiny lobster (*Palinurus*), are mistaken for crayfishes or lobsters, but they differ from them in the absence of the large grasping claws.

Along almost any coast some of these animals are to be found, often beautifully colored and harmonizing with the seaweeds among which they live, or so transparent that their internal organization may be distinctly seen. Farther out at sea other species swim in incredible numbers, feeding upon minute organisms, and in turn fed upon by numerous fishes and whales; and, especially on the Pacific coast, shrimp-fishing is an important industry.

103. **The hermit-crabs.**—The last of these long-tailed decapods is the interesting group of the hermit-crabs, which occur in various situations in the sea. In early life they take possession of the empty shell of some snail, and the protected abdomen becomes soft and flabby, while the appendages in this region almost completely disappear. The front part of the body, on the other hand, continually grows in firmness and strength, and is admirably adapted for the continual warfare which these forms wage among themselves. As growth proceeds the necessity arises for a larger shell, and the crab goes "house-hunting" among the empty shells along the shore, or it may forcibly extract the snail or other hermit from the home which strikes its fancy.

Many of the hermit-crabs enjoy immunity from the attacks of their belligerent relatives by allowing various hydroids to grow upon their homes. Others attach sea-anemones to their shells or to one of their large claws,

which they poke into the face of any intruder. While the anemones or hydroids are made to do valiant service



FIG. 60.—Hermit-crab (*Pagurus bernhardus*) in small shell covered with *Hydractinia*.

with their nettle-cells, they also enjoy the advantages of a large food-supply which is attendant upon the free ride.

104. **The crabs.**—The most highly developed Crustacea are the crabs or short-tailed decapods which abound between tide-marks alongshore, and in diminishing numbers extend to great depths. The cephalothorax is usually relatively wide, often wider than long, and the greatly reduced abdomen is folded against the under side of the thorax. Correlated with the small size of the abdomen, the appendages of that region disappear more or less, but the remaining appendages are similar to those of the crayfish or lobsters. All these different parts, however, are variously modified in each species to fit it for its own peculiar mode of life. In some forms, such as the common cancer-crab (Fig. 61), the legs are comparatively thick-set and possessed of great strength, enabling them to defend themselves against most enemies. On the other hand, there are the spider-crabs with small bodies and relatively long legs, withal weak, and

yet so harmonizing with their surroundings that they are as likely to survive as their stronger relatives. In this



FIG. 61.—Kelp-crab (*Epiplatys productus*) in upper part of figure; to the right the edible crab (*Cancer productus*), and the shore-crab (*Pugettia richii*).

connection it is interesting to note that the giant crab of Japan, the largest crustacean, being upward of twenty feet from tip to tip of the legs, is a spider-crab, constructed on



FIG. 62.—The fiddler-crab (*Gelasimus*). Photograph by Miss MARY RATHBUN.

the same general pattern as our common coast forms. Between these two extremes numberless variations exist,

some for known reasons, but more often not readily understood. And not only does the form vary, but the external surface may be sculptured or beset with spines or tubercles which frequently render the animal inconspicuous amid its natural surroundings. Such an effect is heightened by the presence of sponges, hydroids, and various seaweeds which the crab often permits to gather upon its body.

105. **Pill-bugs and sandhoppers.**—Finally there remain the groups of the pill- or sow-bugs (Isopods) and the sand-fleas or sandhoppers (Amphipods). In the first of these the body is usually small and compressed, the thorax more or less plainly segmented, and the seven walking (thoracic) legs are similar. In the female each leg bears at its base a thin membranous plate which extends inward and hori-

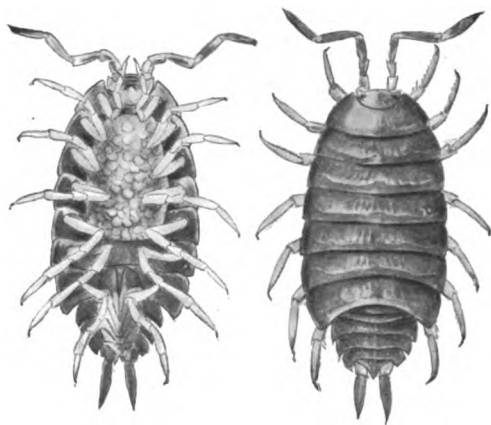


FIG. 63.—Isopod or pill-bug (*Porcellio laevis*).

zontally, thus forming on the under side of the body a brood-pouch (Fig. 63) in which the young develop. As one may readily discover in any of the common species, the abdominal segments are more or less fused, and bear appendages adapted for respiration and, in the aquatic forms, for swimming.

The marine isopods occur in the sand, under rocks, and in the seaweeds; many are parasitic upon fishes; and the terrestrial forms (Fig. 63) are very common objects under old

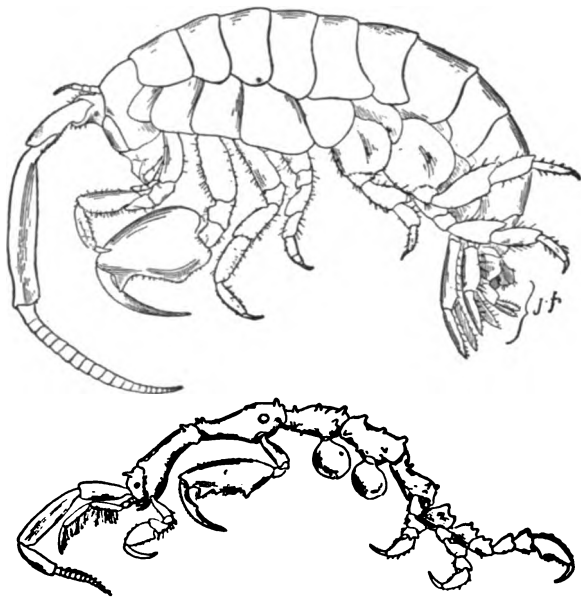


FIG. 64.—Amphipods or sand-fleas (*Gammarus*, upper species, and *Caprella*).

logs and in cellars, where they live chiefly on vegetable matter. In the sand-fleas the body is compressed from side to side, and while the thorax shows distinct segments, the legs are frequently dissimilar, and some may bear pincers. One of their most distinctive marks concerns the last three abdominal appendages, which are usually modified for leaping.

The sand-fleas (Fig. 64) are familiar objects to any one who has collected along the beach and has turned over the cast-up seaweeds, while numbers of small species often occur among the plants in our fresh-water ponds. Some most curious and highly modified forms, whose general appearance is shown in the lower part of Fig. 64, occur among

hydroid colonies, with which their bodies harmonize in form and color. And, lastly, most bizarre creatures, known as "whale-lice," attach themselves to the skin of whales, of which each species acts as host for one or more kinds.

106. **Internal organization.**—Most Crustacea are carnivorous, preying upon almost any of the smaller animals within convenient reach; a much smaller number live on vegetable food; and there are many, such as the crayfishes, lobsters, and numerous crabs, which are also notorious scavengers. In these latter forms the food is held in one of the large pincers, torn into shreds by the other, and transferred to the mouth-parts, where, as in all Crustacea, it is soon reduced to a pulp by their rapid movements. In many species the food is now ready for the digestive process, but not so in the higher forms. If the stomach of any of these, for example, the crabs or crayfishes, be opened, three (Fig. 65, *s*) large teeth operated by powerful muscles will be noted, and beyond these a strainer consisting of many closely set hairs. In operation this "gastric mill" takes the food passed on from the mouth-parts, and crushes and tears it until fine enough to pass through the strainer, whereupon it is dissolved by the juices from the liver and is absorbed as it passes down the intestine.

The circulatory system is usually highly developed, and consists of a heart, in some species almost as long as the body, though usually shorter (Fig. 65), from which two or more arteries branch to all parts of the body. Here the blood, instead of emptying into definite veins, pours into a series of spaces or sinuses in among the muscles and other organs of the body, through which it makes its way back to the heart. During this return journey it is usually made to traverse definite respiratory organs, either situated upon the legs or, as feathery outgrowths, upon the sides of the body, and generally concealed under the carapace. A portion of the blood is also continually sent to the kidneys, which are located either at the base of the second antennæ

(and known as green glands), as in the crayfishes or crabs, or on the second maxillæ (shell-glands) in many of the

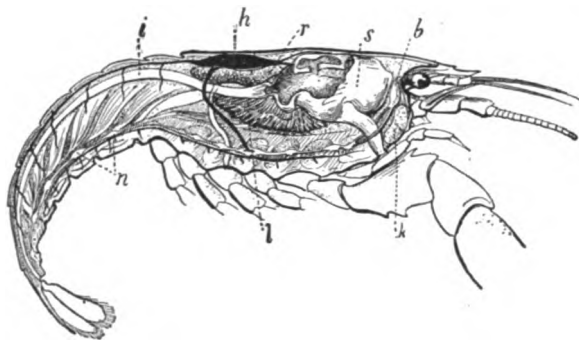


FIG. 65.—Dissection of crayfish. *b*, brain; *h*, heart; *i*, intestine; *k*, kidney; *l*, liver; *n*, nerve-cord; *r*, reproductive organ; *s*, stomach, showing two teeth in position.

simpler crustaceans. Their method of operation is much like that of the kidneys in the earthworm.

107. Nervous system and special senses.—The nervous system also shows a decided resemblance to that of the annelids. The cerebral ganglia or brain is situated above the alimentary canal in the head, and connects with the ventrally lying cord by a collar. As in the earthworm, this ventral cord is double, and bears a pair of swellings or ganglia in each segment. In the crayfish, crabs, and other highly modified forms, where the segments tend to fuse, several of these ganglia may also unite, and except in early life their number cannot be determined.

Among the less specialized Crustacea the order of intelligence is low, though perhaps it may prove to be higher than is usually supposed when such forms have been more thoroughly studied. The following quotation relating to the lobster applies even more to the higher forms, the crabs: "Sluggish as it often appears when out of water and when partially exhausted, it is quite a different animal when free to move at will in its natural environment on the sea-

bottom. It is very cautious and cunning, capturing its prey by stealth, and with weapons which it knows how to conceal. Lying hidden in a bunch of seaweed, in a crevice among the rocks, or in its burrow in the mud, it waits until its victim is within reach of its claws, before striking the fatal blow. The senses of sight and hearing are probably far from acute, but it possesses a keen sense of touch and of smell, and probably also a sense of taste."

Although enclosed in a horny and often very thick and strong armor, the sense of touch is very keen in the Crustacea and in arthropods generally. On many of the more exposed portions delicate hairs or pits connected with the nervous system occur in great abundance. Some of these, usually on the antennæ, undoubtedly serve in detecting odors, but the remainder are considered to be tactile. In the higher Crustacea, such as the crayfish, lobsters, and crabs, ears are usually found, consisting of sacs lined with similar delicate hairs, and containing several minute grains of sand, which in many cases make their way through the small external opening. Vibrations coming through the water gently shake the grains of sand, causing them to strike against the hairs which communicate with the nervous system—a very simple ear, yet sufficient for the needs of the animals.

The eyes of the Crustacea and arthropods in general are either simple or compound. The simple and frequently single eyes usually consist of a relatively few cells embedded in a quantity of pigment and connected with the nervous system. It is doubtful whether they perceive objects as anything more than highly blurred images, and perhaps they merely recognize the difference between light and darkness. The compound eyes, on the other hand, are remarkably complex structures, often borne on the tops of movable stalks, as in the common crabs and crayfishes. Each consists of an external transparent cornea, divided into numerous minute hexagonal areas corresponding to as

many internal rods of cells, provided with an abundant nerve-supply. These latter elements may perhaps represent simple eyes grouped together to form the compound one; and it appears possible that each element may form a complete image of an object, as each of our eyes is known to do. On the other hand, many hold that the complete eye forms only one image, a mosaic, each element contributing its share.

108. Growth and development.—As we have seen, the simpler Crustacea hatch as minute larvæ (Fig. 56), and during their growth to the adult condition are especially subject to the attacks of multitudes of hungry enemies. In the higher forms, such as the crabs, some of these early transformations take place while the young are still within the egg and attached to the parent. Accordingly, the little ones are fairly similar to their parents, and their later history is very well exemplified by the lobster.

The eggs of the lobster are most frequently hatched in the summer months, usually July, after they have been carried by the parent for upward of a year. The young, about a third of an inch in length, at once disperse, undergo four or five moults during the next month, then, ceasing their swimming habits, settle to the bottom among the rocks. At this time, twice their original size, they closely resemble their parents, and their further development is largely an increase in size. "The growth of the lobster, and of every arthropod, apparently takes place, from infancy to old age, by a series of stages characterized by the growth of a new shell under the old, by the shedding of the outgrown old shell, a sudden increase in size, and the gradual hardening of the shell newly formed. Not only is the external skeleton cast off in the moult and the linings of the masticatory stomach, the esophagus, and intestine, but also the internal skeleton, which consists for the most part of a complicated linkwork of hard tendons to which muscles are attached."

109. **Peripatus** (class **Onychophora**).—It is generally believed that the Crustacea, insects, and spiders, together with their numerous relatives, trace their ancestry back to animals that bore a certain resemblance to the segmented worms. Most of these ancient types have long been extinct, but here and there throughout the earth we occasionally meet with them.

Among the most interesting of these are a few widely distributed species belonging to the genus *Peripatus* (Fig. 66), but as they are comparatively rare we shall dismiss them with a very brief description. They usually dwell in warm countries, under rocks and decaying wood, emerging at night to feed on insects, which they ensnare in the slime thrown out from the under surface of the head. Their external form, their excretory system, and various other organs are worm-like. On the other hand, the appendages are jointed, and one pair has been modified into jaws. The peculiar breathing organs characteristic of the insects are also present. *Peripatus* therefore gives us an interesting link between the worms and insects, and also affords an idea of the primitive insects from which the modern forms have descended.

110. **The centipeds and millipeds** (class **Myriapoda**).—Many of the myriapods—that is, the centipeds and thousand-legged worms—are familiar objects under logs and stones throughout the United States. The first of these (Fig. 67) are active, savage creatures, devouring numbers of small animals, which they sting by means of poison-spines on the tips of the first pair of legs. The bite of the larger tropical

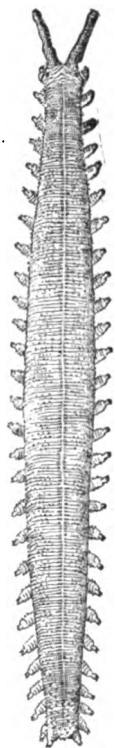


FIG. 66.—*Peripatus* (*Peripatus elsent*).
Twice the natural size.

species especially causes painful but not fatal wounds in man.

On the other hand, the millipeds (Fig. 68) or thousand-legs are cylindrical, slow-going animals, feeding on vegetable



FIG. 67.—Centiped.
One-half natural size.



FIG. 68.—Thousand-legs or milliped (*Julus*).
Natural size.

substances without causing any particular damage, except in the case of certain species, which work injury to crops. When disturbed they make little effort to escape, but roll into a coil and emit an offensive-smelling fluid, which renders them unpalatable to their enemies.

All present a great resemblance to the segmented worms, as their popular names often testify; but, on the other hand, many points in their organization indicate a closer relationship to the insects. As in the latter, the head is distinct, and bears a pair of antennæ, the eyes, and two or three pairs of mouth-parts. The trunk is more worm-like, and consists of a number of similar segments, each bearing

one or two pairs of jointed legs. In their internal organization the character of the various systems closely resembles that of the insects, and will be more conveniently described in that connection.

Among the myriapods the females are usually larger than the males. Some of the centipeds deposit a little mass of eggs in cavities in the earth and then abandon them, while others wrap their bodies about them and protect them until the young are hatched. The millipeds lay in the same situations, but usually plaster each egg over with a protective layer of mud. After several weeks the young appear, often like their parents in miniature, but in other species quite unlike, and requiring several molts to complete the resemblance.

CHAPTER X

ARTHROPODS (*Continued*). CLASS INSECTS

111. **Their numbers.**—It has been estimated that upward of three hundred thousand named species of insects are known to the zoologist, and that these represent a fifth, or possibly a tenth, of those living throughout the world. Many of these species, as the may-flies and locusts, are represented by millions of individuals, which sometimes travel in such great swarms that they darken the sky. With nearly all of these the struggle for existence is fierce and unrelenting, and it is little wonder that such plastic animals have changed in past times and are now becoming modified in order to adapt themselves to new situations where food is more abundant and the conditions less severe. Owing to such modifications we find some species fitted for flying, others for running and leaping, or for a life underground, and many for a part or all of their lives are aquatic in their habits.

112. **External features.**—The body of an insect—the grasshopper, for example—consists of a number of rings arranged end to end, as we have seen them in the Crustacea and the segmented worms. In the abdomen these are clearly distinct, but in the thorax, and especially the head, they have become so intimately united that their number is a matter of uncertainty. These three regions—head, thorax, and abdomen—are usually clearly defined in most insects, but they are modified in innumerable ways in accordance with the animal's mode of life.

The head usually carries the eyes, a pair of feelers (antennæ), and three pairs of mouth-parts which may be fashioned into a long, slender tube to be used in sucking, and frequently as a piercing organ ; or they may be constructed for cutting and biting. The thorax bears three pairs of legs and often one or two pairs of wings. The appendages of the abdomen are usually small and few in number, or even absent.

113. Internal anatomy.—The restless activity of insects is proverbial. Some appear to be incessantly moving about, either on the wing or afoot, and are endowed with comparatively great strength. Ants and beetles lift many times their own weight. Numerous insects are able to leap many times their own length, and others perform different kinds of work with a vigor and rapidity unsurpassed by any other class of animals. As is to be expected, the muscular system is well developed, and exhibits a surprising degree of complexity. Over five hundred muscles are required for the various movements of our own bodies, but in some of the insects more than seven times this number exist. The amount of food necessary to supply this relatively immense system with the required nourishment is correspondingly large. Many insects, especially in an immature or larval condition, devour several times their own weight each day. Their food may consist of the juices of animals or plants, which they suck out, or of the firmer tissues, which are bitten or gnawed off.

Not only do the mouth-parts stand in direct relation to the habits of the animal and to its food, but, as we have often noticed before, the internal organization is also adapted for the digestion and distribution of the nutritive substances in the most economical way. For this reason we find the alimentary canal differing widely in the various forms of insects. In each case it extends from the mouth to the opposite end of the animal, and ordinarily consists of a number of different parts. In the insect shown in

Fig. 69 the mouth soon leads into the esophagus, which in turn leads into the crop that serves to store up the food until ready for its entry into the stomach; or in some of the ants, bees, and wasps it may contain material which

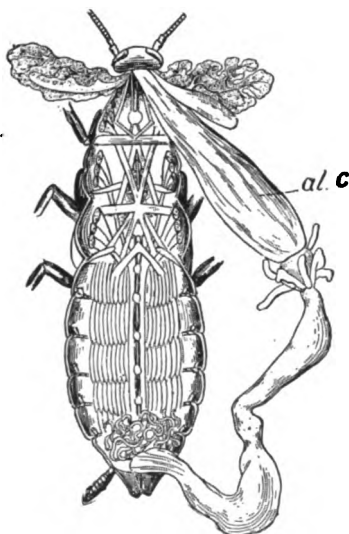


FIG. 69.—Cockroach, dissected to show alimentary canal, *al. c.*—After HATSCHKE and COBL.

may be disgorged and fed to the young. In many cases the stomach is small and ill-defined as in Fig. 69, and again it may reach enormous dimensions, nearly filling the body. It may also bear numerous lobes or delicate hair-like processes, which afford a greater surface for the absorption of food. Behind the stomach are a number of slender outgrowths that are believed to act as kidneys. Beyond their insertion lies the intestine, which, like the stomach, is the subject of many modifications in the different kinds of insects.

The digested food is rapidly absorbed through the coats of the stomach and intestine and enters a circulatory system which reminds us of what exists in many of the Crustacea. The heart is situated above the digestive tract, and from it arteries pass out to different parts of the body. Here the blood leaves the vessels and is poured directly into the spaces among the viscera, whence it is finally conducted through irregular channels to the heart by its pulsations.

In the Crustacea the blood is made to pass through a respiratory system usually in the form of definite gills, and the oxygen with which it is charged is distributed to all

parts of the body. In the insects the blood serves almost entirely to carry the food, and the oxygen is conveyed through the animal by a remarkable contrivance found only in the insects, the spiders, and a few related forms.

114. **Respiratory system.**—If we examine an insect, the grasshopper for example, we find a number of small brown spots on each side of the abdomen, each of which under a magnifying-glass is seen to be perforated by a narrow slit. Carefully opening the body, we find that each slit is in communication with a white, glistening tube that rapidly branches and penetrates to all parts of the animal. When the body is expanded the air rushes into the outer openings, on through the open tubes, and is distributed with great rapidity to all the tissues of the body. In many insects some of these tubes connect with air-sacs which probably serve to buoy up the insect during its flights through the air.

115. **Wingless insects (Thysanura).**—The simplest of all insects are the fishmoths and springtails, relatively small organisms covered with shining scales or hairs. The first of these is occasionally seen running about in houses feeding upon cloth and other substances, while the latter live in damp places under stones and logs. They are without wings, but are able to run rapidly and to leap considerable distances. In addition to the ordinary appendages, the abdomen bears what are perhaps rudimentary legs, a fact which, together with their relatively simple structure, strengthens the belief that the insects have descended from centiped-like ancestors.

116. **Grasshoppers, crickets, katydids, etc. (Orthoptera).**—Rising higher in the scale of insect life, we arrive at the group of the cockroaches, crickets, grasshoppers, locusts, and other related insects. Four wings are present, the first pair thickened and overlapping the second thinner pair. The latter are folded lengthwise like a fan, which is said to have given the name *Orthoptera* (meaning straight-winged) to

this group of insects. These extend all over the world, being particularly abundant in the warmer countries, and their strong biting mouth-parts and voracious appetites render many of them dreaded pests to the farmer. The cockroaches are nocturnal in their habits, racing about at night, devouring victuals in the pantry and gnawing the bindings of books. During the day their flat bodies enable them to secrete themselves in crevices wherever there is sufficient moisture.

In the grasshoppers, locusts, katydids, and crickets the body is more cylindrical, and the hind pair of legs are often greatly lengthened for leaping. The crickets and katydids



FIG. 70.—The Rocky Mountain locust.—
After RILEY, from *The Insect World*.

are nocturnal, the former remaining by day in burrows which they construct in the earth, the latter resting quietly in the trees. At night they feast upon vegetable matter principally, though

some species are known to prey on small animals. Those insects we usually term grasshoppers (properly called locusts) are specially destructive to vegetation. Some species are strong fliers, and this, connected with their ability to multiply rapidly, renders them greatly dreaded pests. They have been described as flying in great swarms, forming black clouds, even hiding the sun as far as the eye could reach. The noise made by their wings resembled the roar of a torrent, and when they settled upon the earth every vestige of leaf and delicate twig soon disappeared.

The eggs of the majority of Orthoptera are laid in the ground, where they frequently remain through the winter. When hatched the young quite closely resemble the parents, and, after a relatively slight metamorphosis, assume the adult form.

117. Dragon-flies, may-flies, white ants, etc. (Pseudoneuroptera).—The dragon-flies, caddis-flies, may-flies, and white ants

possess four thin and membranous wings incapable of being folded. These possess a network of delicate nervures, giving the name Neuroptera (meaning nerve-winged) to the class. Of the forms mentioned above, all but the white ants lay their eggs in the water, and the developing larvæ

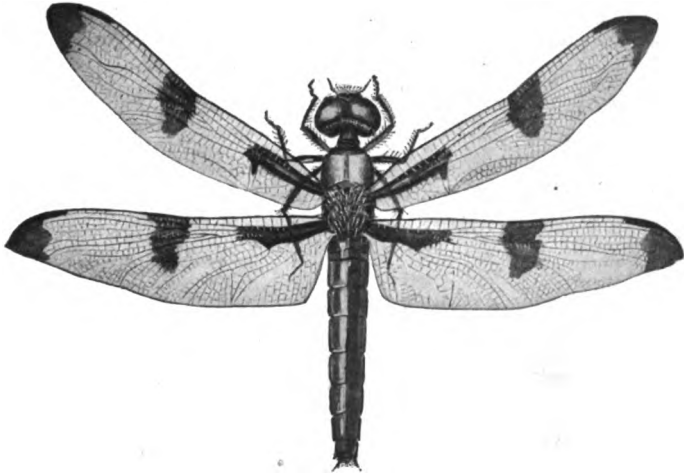


FIG. 71.—Dragon-fly (*Libellula pulchella*).

spend their lives in this medium until the time comes for their complete metamorphosis into the adult. The larvæ of the caddis-flies protect themselves within a tube of stones or sticks bound together with silken threads, which they usually attach to the under side of stones in running water. On the other hand, the young of the dragon- and may-flies, provided with strong jaws, are active in the search of food and very voracious. In time they emerge from their larval skin and the water in which they live, and after a life spent on the wing they deposit their eggs and perish. The adult ant-lion, a type of the related order (Neuroptera), which has somewhat the appearance of a small dragon-fly, lays its eggs in light sandy soil. In this the resulting larvæ excavate funnel-shaped pits, at the bottom of which they lie con-

cealed. Insects stumbling into their pitfalls are pelted with sand, which the ant-lion throws at them with a jerky motion of the head, and are speedily tumbled down the shifting sides of the funnel to be seized and devoured.

While the white ants are not in any way related to the true ants, they possess many similar habits. Associated in great companies, they excavate winding galleries in old logs and stumps, and, further, are most interesting because of the division of labor among the various members. The wingless forms are divided into the workers, which excavate, care for the young, and otherwise labor for the good of the others; and into the soldiers, huge-headed forms,

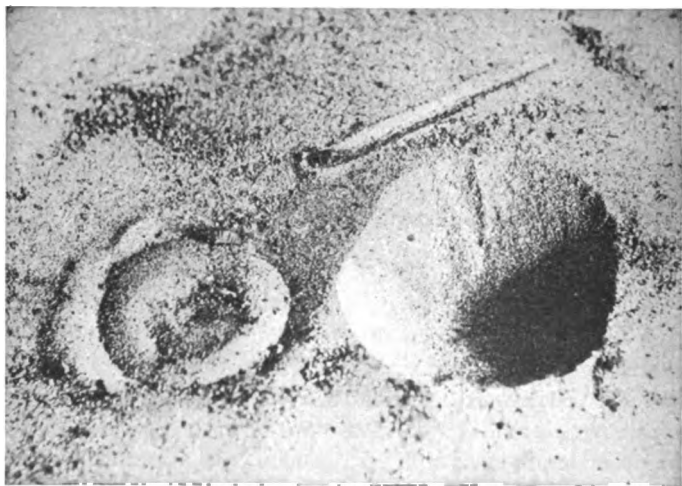


FIG. 72.—Ant-lion larva plowing its way through the sand (upper figure) while another is commencing the excavation of a funnel-shaped pit similar to one on right. Photograph by A. L. MELANDER and C. T. BRUES.

whose strong jaws serve to protect the colony. The remaining winged forms are the kings and queens. In the spring many of the royalty fly away from home, shed their wings, unite in pairs, and set about to organize a colony. The queen rapidly commences to develop eggs, and in some

species her body becomes so enormously distended with these that she loses the power of locomotion and requires to be fed. A single queen has been known to lay eggs at the rate of sixty per minute (eighty thousand a day), and

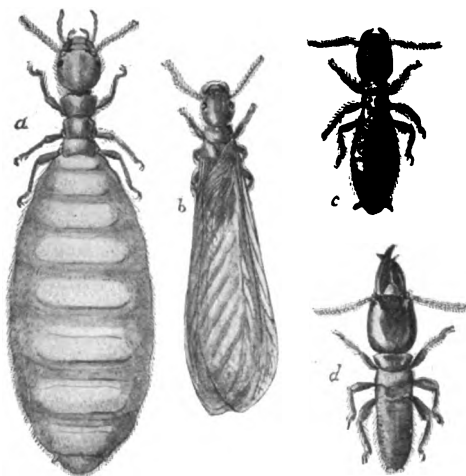


FIG. 73.—Termites or white ants. *a*, queen; *b*, winged male; *c*, worker; *d*, soldier.

those destined to royal rank are so nursed that they advance farther in their development than the remaining sterile and wingless forms.

118. The bugs (*Hemiptera*).—The large and varied group of the bugs (*Hemiptera*) includes a number of semi-aquatic species, such as the water-boatmen, often seen rowing themselves along in the ponds by means of a pair of oar-shaped legs, in search of other insects. Somewhat similar at first sight are the back-swimmers, with like rowing habits, but unique in swimming back downward. Both of these bugs frequently float at the surface, and when about to undertake a subaquatic journey they may be seen to imprison a bubble of air to take along. Closely related are the giant water-bugs (Fig. 74), which often fly from pond to pond at night. In such flights they are frequently

attracted by lights, and have come to be called "electric-light bugs."

Among our most dreaded insect pests are the chinch-bugs—small black-and-white insects, but traveling in companies aggregating many millions. As they go they feed upon the stems and leaves of grain, which they devour with extraordinary rapidity. The squash-bug family is also extensive, and destructive to the young squash and pumpkin plants in the early spring.



FIG. 74.—Giant water-bug (*Serphus dilatatus*), with eggs attached.

The lice are small, curiously shaped bugs, which suck the blood of other animals. The plant-lice, also small, suck the juices of plants, and are often exceedingly destructive. This is especially true of the phylloxera, a plant-louse which causes annually the loss of millions of dollars among the vineyards of this and other countries.

Even more destructive are the scale-insects, curiously modified forms, of which the wingless females may be found on almost any fruit-tree and on the plants in conservatories, their bodies covered with a downy, waxy, or other kind of covering, beneath which they remain and lay their eggs.

119. The flies (Diptera).—The group of the Diptera (meaning two-winged) includes the gnats, mosquitoes, fleas, house-flies, horse-flies (Fig. 75), and a vast company of related forms. Only a single pair of wings is present, the second pair being rudimentary or fashioned into short, thread-like appendages known as balancers, though they probably act as sensory organs and are not directly concerned with flight. The mouth-parts are adapted for piercing and sucking. The eyes, constructed on the same plan

as those of the Crustacea, are comparatively large, and are frequently composed of a great number of simple eyes united together, upward of four thousand forming the eye of the common house-fly.

These insects are widely distributed throughout the world, where they inhabit woods, fields, or houses as best suits their needs. Their food is varied. Some suck the juices of plants, others attack animals, and, while many are troublesome pests, others, especially in the early stages of their existence, are of great benefit.

120. Familiar examples.—Owing to the widely different habits and structure of the members of this group, we shall briefly consider two examples, the mosquito and the house-fly, which will give us a fairly good idea of the characteristics of all. The eggs of the mosquito are laid in sooty-looking masses on the surface of stagnant pools. Within a very short time the young hatch, and, owing to their peculiar swimming movements, are known as “wrigglers.” They are then active scavengers, devouring vast quantities of noxious substances and performing a valued service. They frequently rise to the surface, take air into the tracheal system, which opens at the posterior end of the body, and descend again. After an increase in growth and many internal changes resulting in a chrysalis-like stage, they rise to the surface, split the shell, and, using the latter as a float, carefully balance themselves and soon fly away.

The house-fly usually lays its eggs in decaying vegetable matter, and the young, maggot-like in form, are active scavengers. They too undergo deep-seated changes during the next few days, finally transforming into the adult.



FIG. 75.—Horse-fly (*Therio-plectes*).

Many of this great group of the flies spend their early life in the water or other medium acting as scavengers; but, on the other hand, numbers attack domestic and other animals, and throughout their entire lives are an intolerable plague.

121. **The beetles (Coleoptera).**—Owing to the ease of preservation and their bright colors, the beetles have probably been more widely collected than other insects. Fully ten

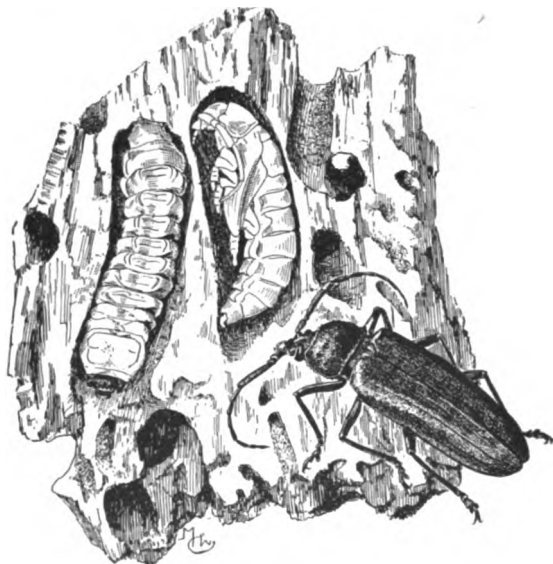


FIG. 76.—Long-horned borer (*Ergates*). Larva (left-hand figure), pupa, and adult insect.

thousand distinct species are known in North America alone. They are all readily recognized by the two firm, horny sheaths enclosing the two membranous wings, which alone are organs of flight. The mouth is provided with jaws, which are used in gnawing. Some prey on noxious insects or upon decaying vegetable or animal matter, and are often highly beneficial; but others attack our trees and domestic animals, and work incalculable damage.

In some of the stag- or wood-beetles (Fig. 76), which we may select as types, the adults are often found crawling about on or beneath the bark of trees, living on sap or small animals. The eggs laid in these situations develop into grub-like larvæ, which bore their way through living or dead wood, and in this condition sometimes live four or five years. They then transform into quiescent pupæ (Fig. 76), which finally burst their shells and emerge in the adult form. Others, like water-beetles and the whirligig-beetles, whose mazy motions are often seen on the surface of quiet streams, pass the larval period in the water. Under somewhat different conditions we find the potato-bugs, lady-bugs, fire-flies, and their innumerable relatives, but the changes they undergo in becoming adult are essentially the same as those described for the other members of the order.

122. **The moths and butterflies (Lepidoptera).**—The moths and butterflies occur all over the world. In their mature



Fig. 77.—Monarch-butterfly (*Anosia plexippus*). From photograph by A. L. MELANDER and C. T. BRUES.

state they are possessed of a grace of form and movement and a brilliancy of coloration that elicit our highest admiration. The mouth-parts are developed into a long proboscis, which may be unrolled and used to suck the nectar out of flowers, though in many of the adult moths, which never feed, it may remain unused. The wings, four in number, are covered with beautiful overlapping scales that

adhere to our fingers when handled. This feature, and the general plan of the body, which is much the same



FIG. 78.—The silver-spot (*Argynnis cybele*). Photograph by A. L. MELANDER and C. T. BRUES.

throughout the group, enables us to recognize most of them at once.

123. Development and metamorphosis.—In some of the simplest insects, as in the bugs, the young at birth resemble their parents. In other insects the resemblance is not so close. The young grasshopper, for example, hatches, from an egg laid in the ground, with a ridiculously large head and staring eyes; still there is no difficulty in recognizing its relationships. During the next week internal changes take place. The shell is burst, and the grasshopper emerges, looking more like its parents than before. This process is repeated four or five times during the next few weeks, and the gradual changes thus produced finally bring the young insect to the adult form. This latter state has been attained by an *incomplete metamorphosis*.

In the flies, beetles, butterflies, and numerous insects the differences between the newly hatched young and the adult are vastly greater. No one looking on a caterpillar or a grub for the first time would suspect its origin, and the changes they undergo have attracted attention for centuries. Placing any of the ordinary caterpillars with their favorite food in a glass-covered box, we may readily watch their transformations. Provided with biting mouth-parts and a voracious appetite, they devour vast quantities of vegetation for several days. Finally they cease eating, and

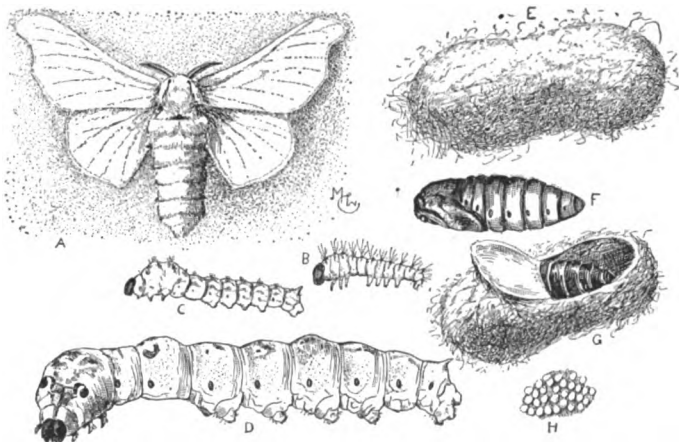


FIG. 79.—Life-history of silk-moth (*Bombyx mori*). A, adult; B, C, D, caterpillars of different ages; E, F, G, silken cocoon and pupa; H, eggs.

suspend themselves head downward by means of a kind of cobweb. After remaining quiet a few hours, they burst their skin, and within appears a chrysalis or pupa. In the moths, for example, the silk-moth (Fig. 79), the caterpillar or silk-worm, after eating the favorite mulberry leaves, spins a silken cocoon, in which the pupa is produced. The larvæ of beetles and many other insects excavate tunnels in wood or in the earth, and there undergo their transformations. Invariably the pupa remains quiet for days, months,

or even years, but when the proper time arrives the fully formed insect emerges, and takes to the wing.

Wonderful internal changes have been taking place during this time. The organs fitted for the proper treatment of the vegetable food of the caterpillar or grub are destroyed, at least in part, and new systems are produced ready for the nectar and vegetable juices which are to be the food of the adult insect. All insects that pass through a pupal quiescent stage are said to undergo a *complete metamorphosis*.

124. The ants, bees, wasps, etc. (Hymenoptera).—The ants, bees, and wasps are the best-known insects belonging to this order. They are characterized by four membranous wings, by biting and sucking mouth-parts, and the female is often provided with a sting. All undergo a complete metamorphosis. The eggs may be laid in the bodies of other insects, many of which are pests, and are thus destroyed; or they may be deposited in the nests of other insects, the foster-parents being compelled to feed them; or they may be placed in marvelously constructed homes, and be the objects of the greatest attention, the parents or attendants often risking or losing their lives in their defense. The members of this order have long attracted attention, largely on account of their remarkable instinctive powers. They live in highly organized communities and certain of their characteristics may be illustrated by a study of some of the more familiar forms.

125. The ants.—The ants live in communities consisting of anywhere from a dozen to many thousands of individuals, according to the species. Each of these colonies contains the queen, several young winged males and females, destined as kings and queens to found new colonies, and of a far greater number of wingless sterile females, the workers. The workers construct the greater part of the nest, which often consists of extensive galleries, nurseries, and granaries, excavated in wood or in the earth. They also attend

to the acquisition of food, which consists of the sweet juices of plants, of other insects, or of leaves and seeds. These may be fed at once, or placed in storehouses until times of need.

Certain species of ants make carefully planned attacks upon other weaker forms. The young are carried off, at times only after a prolonged and fierce struggle, and all are soon eaten, or a few may be allowed to develop and act as slaves. Some species are unable to exist without servants, which feed them, wash them, and otherwise minister to their comfort.

In some of their raids numerous plant-lice (delicate, usually green, insects, such as occur on our household plants) are often captured and carried into the nest. These so-called "ant-cows" are carefully tended, and in return yield up a tiny drop of a sugary fluid to the hungry ant that solicits it.

The eggs laid by the queen develop into white worm-like creatures, which ordinarily spin cocoons when about to become pupæ. These are incorrectly called "ant-eggs." Many, probably on account of insufficient nourishment, never develop reproductive organs. They become the neuters or workers. The winged royalty fly away from the colony, pair and found homes of their own, and become surrounded by a numerous progeny.

126. **The bees.**—Among the bees we find a considerable number which lead solitary lives, excavating tunnels in earth or wood, as in the case of many of the wasps, but, unlike them, supplying the young with honey or pollen. Others may constitute a band of worthless insects which steal their food from their more industrious relations, in whose nests they also secretly deposit their eggs, leaving the young to be nourished with food rightly belonging to others.

But it is with the social bees we are most familiar—the bumble- and honey-bees. The former usually build in the ground, and form colonies consisting of the queen and from

twenty to two hundred workers. Regular combs are not constructed, the young at first feeding on pollen masses or "bee-bread," and finally spinning cocoons. In the late summer males and females appear, but as winter comes on all perish except the queens, which seek a sheltered place, and in the spring revive to establish new colonies.

In a wild state the honey-bees dwell in cavities of trees and other protected places, where they form colonies,



FIG. 80.—Bumblebee (*Bombus*).

consisting of the queen, of perhaps two hundred males or drones if the nest be examined in the spring and summer, and of a hundred times as many sterile females, the workers. These form among the most highly organized insect societies known. All work for the good of the colony. To each

worker is assigned a definite task, which is never shirked. It must collect the honey, supply the wax for making the comb, take care of the brood, or in other ways minister to the welfare of the community. On the queen devolves the entire task of egg-laying. She may lay three thousand eggs a day, during the breeding season, for the three or four years she lives. The drones or males, after one nuptial flight, are killed or driven from the hive after a life of a month or two. The unfertilized eggs are placed in large cells, and the young fed on pollen develop into males. The fertilized eggs may produce queens or workers at the discretion of the queen. If the latter be desired, the eggs are placed in small cells with a scant amount of food, which apparently causes the reproductive system to remain undeveloped. The same eggs, if placed in the large queen cells and supplied with highly nutritious food, would have developed into queens. When these latter appear they are vigorously attacked and killed

by the parent if not protected by the workers. If the young queen survive, the old queen departs with many of her subjects, and collects them into a dense swarm attached to a limb of a tree, where they remain until scouts return to conduct them to their new home.

127. **The wasps.**—The digger-wasps are frequently to be seen gnawing tunnels in the wood or earth, at the inner end

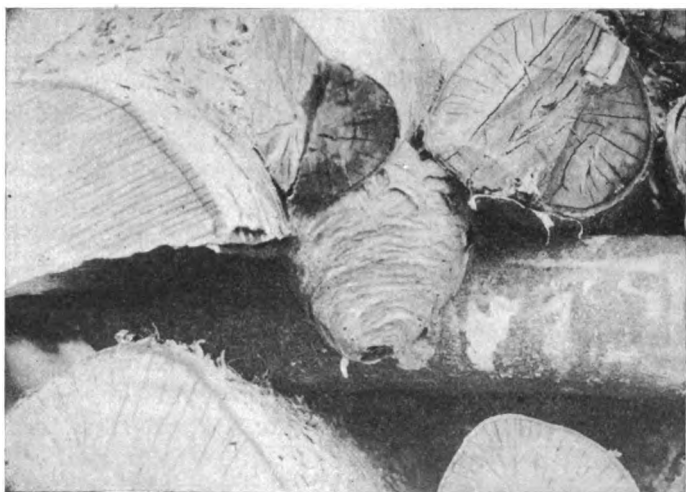


FIG. 81.—Nest of *Vespa*, a social wasp. Photograph by A. L. MELANDER and C. T. BRUES.

of which an egg is laid. In some species the developing young is nourished by food carried in to it day by day. In other cases the parent may never see her child, dying or abandoning it before its birth; but before departing she is careful to place within reach a sufficient supply of spiders, caterpillars, beetles, or locusts that shall nourish the little one until it becomes a motionless pupa. This stage is soon over, and the adult wasp now digs its way to the surface.

Passing by the familiar mud-wasps or mud-daubers, whose nests are common objects under stones or against

the rafters of barns and houses, we arrive at the social wasps. As the name indicates, these insects, such as the yellow-jackets and hornets, live together in companies which consist, as in the ants and bees, of males, females, and workers. They also are fond of the juices of fruits, and many of them destroy insects which may be fed to the young. Their nests are variously situated and constructed, but all of them agree in being composed, at least in part, of a grayish substance which is in reality a kind of paper. With their jaws they scrape off from old logs and fences small particles of wood, which they probably mix with saliva, and rolling the mass into a ball set out for home. These pellets are then flattened out into thin sheets, and worked up into hexagonal cells, in which the eggs are laid.

Along with the nests of the mud-daubers one frequently notices the nests of some of the familiar wasps (*Polistes*), which build cake-like nests composed of thirty or forty hexagonal cells attached by a stalk. Somewhat similar nests, though usually more extensive, are constructed by the yellow-jackets in cavities in the ground. The numerous combs of the hornet are surrounded by several sheets of wood-pulp, and the whole structure is attached generally to the limb of a tree.

In the spring the nests of all these species of wasps are commenced by a single female, who has lived in a dormant condition through the winter. She builds a small nest and in time is surrounded by numerous workers, which live in perfect harmony, enlarging the nest and rearing the young. As autumn approaches the young males and females leave the nest; but the males, together with the workers, all succumb to the cold, and none but the females persist to found a new colony the following spring.

CHAPTER XI

ARTHOPODS (*Continued*). CLASS ARACHNIDA

128. **General characters.**—In this group, comprising the spiders, mites, and a large assemblage of related species, we again meet with great differences in form and structure which fit them for lives under widely different conditions. The three regions of the body, head, thorax, and abdomen, so clearly marked in the insects, are here less plainly defined. The head and thorax are usually closely united, and in the mites the boundaries of the abdomen are also indistinct. The appendages of the head are two in number, and probably correspond to the antennæ and mandibles of other Arthropods. In the scorpions and some species of mites these are furnished with pincers for holding the prey, and in other forms they act as piercing organs. Usually the thorax bears four pairs of legs, a characteristic which readily separates such animals from the insects.

The internal organization differs almost as much as does the external. In many species it shows a considerable resemblance to that of some insects, but in others, especially those of parasitic habits, it departs widely from such a type. Respiration is affected by means of tracheæ, or lung-books, which consist of sacs containing many blood-filled, leaf-like plates placed together like the leaves of a book.

Usually, as in the insects, the young hatch from eggs which are laid, but in the scorpions and some of the mites the young develop within the body and at birth resemble the parent. Almost all of these organisms live either as

parasites or as active predaceous animals upon other animals. For this purpose many are provided with keen senses for detecting their prey and poisonous spines for despatching it.

129. **The scorpions.**—Owing to the stout investing armor, the strong pincers, and the general form of the body, the scorpions might at first sight be mistaken for near relatives

of the crayfish or lobster.

A more careful examination will show that the two pairs of pincers probably correspond to the antennæ and mandibles of the Crustacea that have become modified for seizing the food. The swollen part of the animal lying behind the four pairs of legs is a part of the abdomen, of which the slender "tail" constitutes the remainder. On the tip of the tail is a curved spine supplied with poison glands. Several pairs of eyes are borne on the dorsal surface of the head and thorax, while

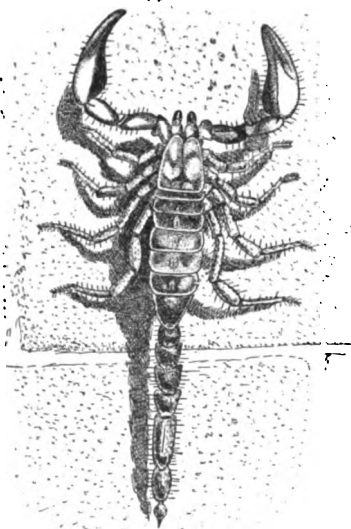


FIG. 82.—Scorpion, showing pincer-like mouth-parts and spine-tipped tail.

on the under side of the animal several slit-like openings lead into as many small cavities containing the lung-books.

The scorpions are the inhabitants of warm countries, where they may be found under sticks and stones throughout the day. At night they leave their homes in search of food, which consists chiefly of insects and spiders. These are seized by means of the pincers, and the sting is driven into them with speedily fatal results. It is doubtful if the poison causes death in man, but the sting of some of the

larger species, which measure five or six inches in length, may produce certain disorders chiefly affecting the circulation. In this country there are upward of thirty species, most of which are comparatively small.

130. The harvestmen.—The harvestmen or daddy-long-legs are small-bodied, long-legged creatures which resemble in general appearance several of the spiders. They differ from them, however, in the possession of claws corresponding to the smaller ones of the scorpion, and in their method of respiration, which is similar to that of insects. During the day they conceal themselves in dark crevices or stride slowly about in shaded places; but at night they emerge into more open districts and capture small insects, from which they suck the juices.

131. The spiders.—The spiders are world-wide in their distribution, and are a highly interesting group, owing chiefly to their peculiar habits. Examining any of our familiar species, it will be seen that the united head and thorax are separated by a narrow stalk from the usually distended abdomen. To the under side of the former are attached four pairs of long legs, a pair of feelers, and the powerful jaws supplied with poison-sacs, while eight shining eyes are borne on the top of the head. On the abdomen, behind the last pair of legs, are small openings into the lung cavities which contain a number of vascular, leaf-like projections known as lung-books. In some species a well-marked system of tracheæ are also present. At the hinder end of the body are four or six little projections, the spinnerets, each of which is perforated with many holes. Through these the secretion from the glands beneath is squeezed out in the form of excessively delicate threads, often several hundred in number, which harden on exposure to the air. According to the use for which these are intended, they may remain a tangled mass or become united into one firm thread; and according to the habits of the animal, they may be used for enclosing their eggs,

for lining their burrows, or for the construction of webs of the most diverse patterns.

132. **The habits of spiders.**—Many species of spiders, some of which are familiar objects in fields and houses, construct sheets of cobweb with a tube at one side in which they may



FIG. 83.—A tarantula-spider (*Eurypelma lentzii*). Natural size. Photograph by A. L. MELANDER and C. T. BRUES.

lie in wait for their prey or through which they may escape in times of danger. In the webs of the common orb- or wheel-weavers several radial lines are first constructed, and upon these the female spider spins a spiral web. Resting in the center of this or at the margin, with her foot on some of the radial threads, she is able to detect the slightest tremor and at once to rush upon the entangled captive.

Some of the bird-spiders and their allies, living in tropical America, and attaining a length of two inches, construct web-lined burrows in the ground. From these they stalk their prey, which consists of various insects and even

small birds. These are almost instantly killed by the poison-fangs, and are then carried to the burrow, where the juices of the body are extracted.

The trap-door spiders of the southwestern section of the United States also dig tunnels, which they cover with a closely fitting lid composed of earth. Raising this they come out in search of insects, but if sought in turn, they dash into the burrow, closing the door after them, and holding it with such firmness that it is rarely forced open. If this should happen, there are sometimes blind passage-ways, also closed with trap-doors, which usually baffle the pursuer.

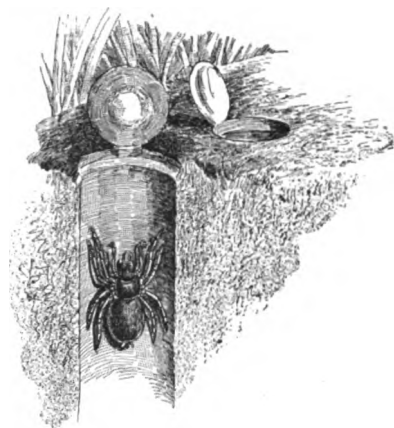


FIG. 84.—Trap-door spider and burrow
(*Cteniza*).

Finally, there are among the thousand species of spiders in the United States a considerable proportion which construct no definite web. Many of these may be seen darting about in the sunshine on old logs and fences, often trailing after them a thread which may support them if they fall in their active leaping after insects.

133. Breeding habits.—The male spiders are usually much smaller than the females, and some species are only one-fifteenth as long as the female and one one-hundredth of its weight. They are usually more brilliantly colored, more active in their movements, yet rarely spinning their own webs and capturing their own food, preferring to live at the expense of the female. At the breeding season the males of several species make a most interesting display

of their colors, activity, and gracefulness before the females; and the latter, after watching these exhibitions, are said to select the one who has "shown off" in the most pleasing fashion. The life after this may be stormy, resulting in the death of the male; but ordinarily the results are not so disastrous, and in a little while the female deposits her eggs in cases which she spins. In these the young develop, sometimes wintering here, and emerging in the spring to scamper about in search of food, or to drift through the air to more favorable spots on fluffy masses of cobweb.

Few groups of animals are more interesting objects of study and more accessible. Their bites are rarely more serious than those of the mosquito—never fatal; and a careful study of any species, however common, will undoubtedly bring to light many interesting and unknown facts.

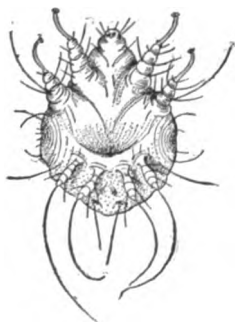


FIG. 85.—The itch-mite (*Sarcoptes scabiei*).

134. **The mites and ticks.**—The mites and ticks are the simplest and among the smallest of the animals belonging to this group. To the attentive observer they are rather common objects, with homes in very different situations. Some occur on living and decaying vegetation, in old flour and unrefined sugar, while others live in fresh water and a few in the sea. Almost all tend toward parasitism. Some of the insects which they pierce and destroy are a pest to man, but on the other hand some are intolerable owing to the diseases they produce.

As to other parasitic organisms, degradation of structure is manifest. The respiratory system, so important to the active life of the insects, may be absent, the animal breathing through its skin. The circulatory system may be wanting, the blood occupying spaces among the various organs being swept about by the animal's movements. And many

other peculiarities have arisen which fit them for their different modes of life.

135. **The king crab (*Limulus*).**—The king crab may be found crawling over the bottom or plowing its way through the sand and mud in many of the quiet bays from Maine to Florida. The large head and thorax of these animals are united into a horse-shoe-shaped piece, behind which lies the triangular abdomen. On the curved front surface of the former are a pair of small median eyes, and farther outward are two larger compound ones. On the ventral side are six pairs of appendages, instrumental in capturing and tearing the small animals that serve as food, and functioning in connection with the terminal spine as locomotor organs. On the

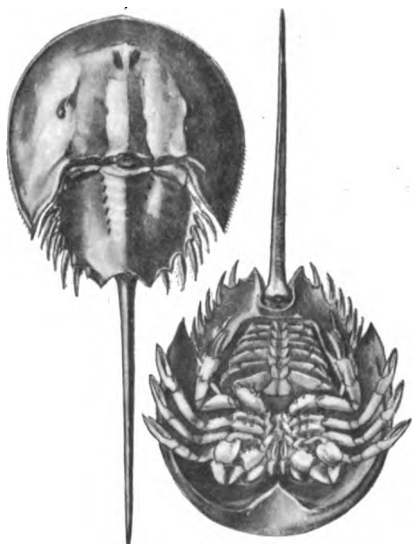


FIG. 86.—The king or horseshoe crab (*Limulus polyphemus*).

ventral surface of the abdomen are numerous plate-like flaps which serve in respiration, and in the imperfect swimming movements in which these animals occasionally indulge.

These relatively large and clumsy creatures are the remnant of a great number of strange, uncouth animals that inhabited the earth in past ages. Many of them show a close resemblance to the scorpions. The anatomy and development also show certain points of resemblance, and by some are thought to give us an idea of the ancient type of spider-like animal from which the modern forms have descended.

CHAPTER XII

ECHINODERMS

136. General characters.—The division of the echinoderms includes the starfishes, sea-urchins, serpent- or brittle-stars, sea-cucumbers, and crinoids or sea-lilies. All are marine forms, and constitute a conspicuous portion of the animals along almost any coast the world over. From these shallow-water situations they extend to the greatest depths of the ocean, and the bodily form possesses a great number of variations, adapting them to lives under such diverse conditions; and yet there is perhaps no group of organisms so clearly defined or exhibiting so close a resemblance throughout. At one time it was thought that their radial symmetry was an indication of a close relationship to the coelenterates, but more careful study has shown them to be much more highly developed than this latter group, and widely separated from it. A skeleton is almost always present, consisting of a number of calcareous plates embedded in the body-wall, and often supporting numbers of protective spines, which fact has given to the group the name Echinoderm, meaning hedgehog skin.

137. External features.—The body of a starfish (Fig. 87) consists of a more or less clearly defined disk, from which the arms, usually five in number, radiate like the spokes of a wheel. At the center of the under side the mouth is located, and from it a deep groove, filled with a mass of tubular feet, extends to the tip of each arm. Innumerable calcareous plates firmly embedded in the body-wall serve

for the protection of the internal organs, and at the same time admit of considerable movement.

In the brittle-stars (Fig. 88) the central disk is much more sharply defined than in the preceding forms, and the long snake-like arms are capable of a very great freedom of movement, enabling the animal to glide over the sea-bottom, or through the crevices of the rocks, at a surprising rate. .

In several species, otherwise closely resembling those

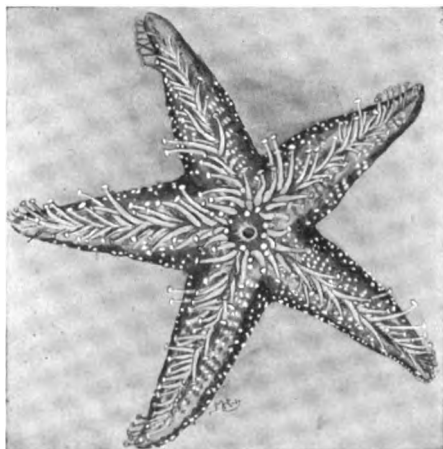


FIG. 87.—Starfish (*Asterias ocracea*), ventral view. One-half natural size.

in Fig. 88, the arms divide repeatedly. These are the so-called basket-stars, living in the deeper waters of the sea, where they, like other brittle-stars, act as scavengers and devour large quantities of decomposing plant or animal remains.

At first sight the globular spiny sea-urchins (Fig. 90) would scarcely be recognized as close relatives of the starfishes. A closer examination, however, shows the mouth to be located on the under side of the body; from it five rows of feet radiate and terminate close to the center of the dorsal side, and the arrangement of the plates forming the

skeleton indicate that the sea-urchin is comparable to a starfish, with its dorsal surface reduced to insignificant proportions.

In the sea-urchins the calcareous plates possess a great regularity, and are so closely interlocked that they prevent

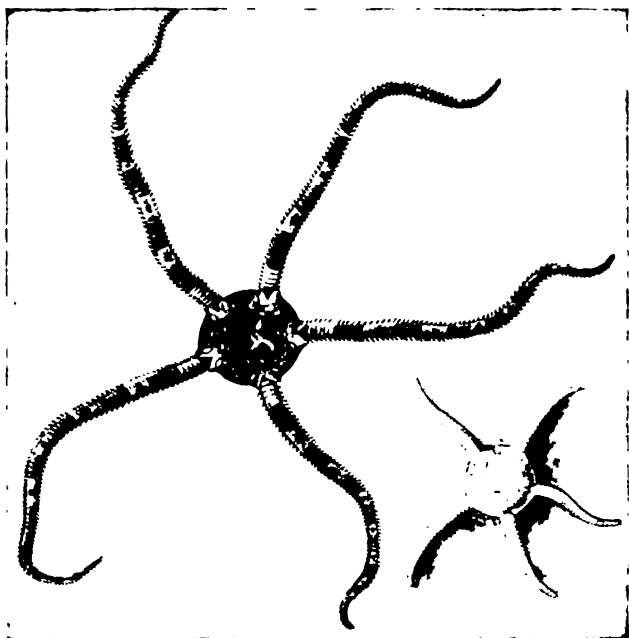


FIG. 88.—Brittle- or serpent-stars (species undetermined). Natural size.

any motion of the body-wall. Also, each plate is usually provided with highly developed spines, movable upon a ball-and-socket joint. These spines serve for locomotion, and, in some instances, for conveying food to the mouth. A considerable number of sea-urchins show an irregularity in form which destroys to a corresponding degree the radial symmetry. This is due to various causes, but especially to a compression of the body, which, in the "sand-dollars,"

has resulted in the production of a thin, cake-like form (Fig. 91).

If the spherical body of a sea-urchin were to be stretched in the direction of a line joining the mouth and the center

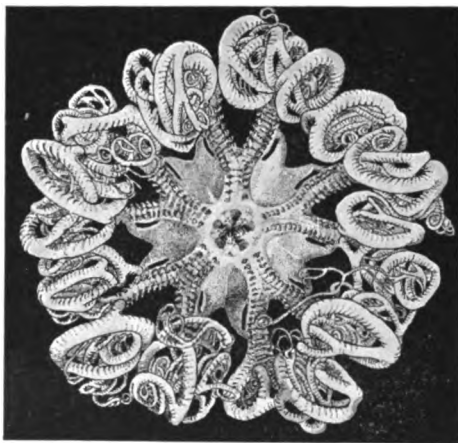


FIG. 89.—Basket-star (*Astrophyton*). One-half natural size.

of the dorsal surface, a form resembling a sea-cucumber (Fig. 92) would be the result. These latter organisms live among crevices of the rocks, embedded in the mud or burrowing in the sand at the bottom of the sea. In such situations they are well protected, and a highly developed skeleton, such as that of the sea-urchin, would not only be of little value, but a positive hindrance to locomotion. The skeleton, therefore, is much reduced, consisting of a few scattered calcareous plates embedded in the fleshy body-wall. Another peculiar feature is almost universally present, in the form of a circlet of tentacles surrounding the mouth, which serve either for the purpose of respiration, for locomotion, or to convey food to the mouth.

A very good imitation of the general plan of a sea-lily or crinoid (Fig. 93) could be made by attaching a serpent-

star, especially one of the basket-stars, by its dorsal side to a stalk. In the crinoids the numerous branches of the

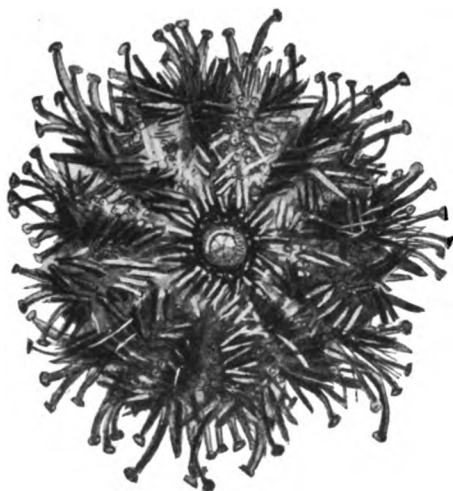


FIG. 90.—Sea-urchin (*Strongylocentrotus purpuratus*).
Natural size.

arms are comparatively short, and in the arrangement of the internal organs there are numerous differences, but for all that the resemblance of these organisms to the other echinoderms is undoubted.

138. **Haunts.** —

The greater number of starfishes occur alongshore, slowly crawling about in search of food, or concealed in dark crevices of

the rocks, where they may often be found as the tide goes out, and we know that in gradually lessening numbers other species lead similar lives at different levels far down in the dark and gloomy depths. In these same locations the sea-urchins occur, sometimes singly, but more usually associated in great numbers, several species excavating hollows in the rocks, within which they obtain protection. The brittle-stars and sea-cucumbers may also be found occasionally in open view, but more often they make their way about in search of food buried in the sand. The crinoids are usually inhabitants of deeper water, where they are found associated often in great numbers. A few species upon attaining the adult condition separate from the stalk, and are able to move about (Fig. 94), but the remaining species never shift their position.

139. **The organs of defense and repair of injury.**—As we have seen, the body-wall of the echinoderms is provided with a series of plates, often bearing spines which serve as organs of defense, and to protect the internal organs. The starfishes and sea-urchins also possess numerous modified spines (*pedicellaria*) scattered over the surface of the body, which have the form of miniature birds' beaks, fastened to slender muscular threads. During life these jaws continually open and close, and it is said they clean the body of *débris* that settles on it; but on the other hand there are several reasons for the belief that they also act as organs of defense. Thus protected, the natural enemies of echinoderms appear to be relatively few, and are confined chiefly to some of the fishes whose teeth are especially modified for crushing them. In this way, and owing to the action of the breakers, they suffer frequent injury, but many species exhibit to a remarkable degree the ability to regenerate lost parts. Experiments show that if all the arms of a starfish be separated from the disk the latter will within two or three months renew the arms; and a single arm with a part of the disk is able to renew the missing portions in about the same length of time.

The brittle-stars, as their name indicates, are usually excessively delicate, often dropping all of their arms upon the slightest provocation; but here again the ability is present to develop the lost portions.

Sea-cucumbers resent rough treatment by vigorously contracting their muscular walls and removing from the body almost the entire digestive tract, the respiratory tree,

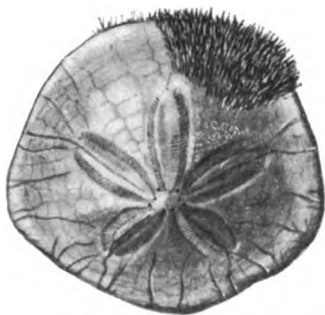


FIG. 91.—Sand-dollar, a flat sea-urchin.
Natural size.

and a portion of the locomotor system; but some species, at least, renew them again.

In some of the starfishes and brittle-stars portions of the body appear to be voluntarily detached and to develop into new individuals, and it is thought that such self-mutilation is a normal method of reproduction.

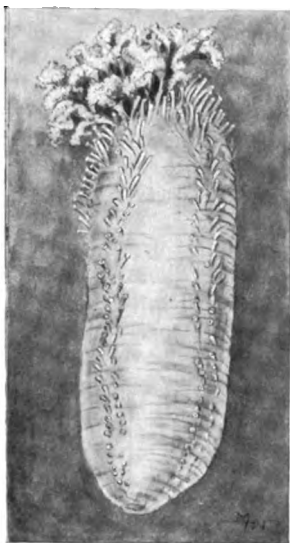


FIG. 92.—Sea-cucumber (*Cucumaria* sp.). Natural size.

140. **Locomotor system.**—One of the most characteristic and remarkable features of the echinoderms is the water-vascular system, a series of vessels containing water which serve in the process of locomotion. Their arrangement and mode of operation are, with slight modifications, the same throughout the group, and may be readily understood from their study in the starfish.

On the dorsal surface of a starfish, in the angle between two of the arms, is a round, slightly elevated, calcareous plate, the *madreporic body* (Fig. 95, *m.p.*), which under the microscope appears full of holes, like the "rose" of a watering-pot. This connects with a tube that passes to the opposite side of the body, where it enters a canal completely encircling the mouth. On this ring-canal a number of sac-like reservoirs with muscular walls are attached, and from it a vessel extends along the under surface of each arm from base to tip. Each of these radial water-mains gives off numerous lateral branches that open out into small reservoirs similar to those located on the ring-canal, and a short distance beyond communicate through the wall of the body with one of the numerous

tube-feet, which, as we have seen, are slender tubular organs, many in number, filling the grooves on the ventral surface of each arm. This entire system of tubes and reservoirs is full of water, taken in, it is said, through the perforated plate, and, when the starfish wishes to advance, many of the little reservoirs contract, forcing water into the cavity of the feet, with which they are in communication, thus extending the extremity of the tubes a considerable distance. The terminal sucker of each foot, acting upon the same principle as those on the cuttlefish, attaches firmly to some foreign object, whereupon the muscles of the foot contract, drawing the body toward the point of attachment. This latter movement is similar to that of a boatman pulling himself to land by means of a rope fastened to the shore. When the shortening of the tube-feet has ceased, the sucking disks release their attachment, project themselves again, and this process is repeated over and over. At all times some of the feet are contracting, and a steady advance of the body is the result.



FIG. 93.—Sea-lily or crinoid.

This method of locomotion also obtains in the sea-urchins and cucumbers, but in the serpent-stars the tube-feet have become modified into feelers, and the animal moves, often rapidly, by means of twisting movements of the arms. The feet have this character also in the crinoids, where the animal is generally without

the power of locomotion. In some of the sea-cucumbers five equidistant rows of tube-feet extend from one end of the body to the other, and the animal crawls worm-like upon any side that happens to be down; but certain species living in the sand,

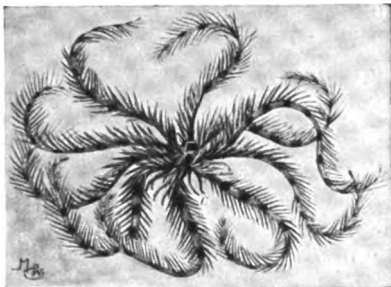


FIG. 94.—An unattached crinoid (*Antedon*). One-half natural size.

where tube-feet will not work satisfactorily, have lost all traces of them, and creep like an earthworm from place to place. In all the sea-cucumbers the feet, situated near the mouth, have been curiously modified to form a circle of tentacles, which range in form from

highly branched to short and thick structures, and in function from respiratory organs and those of touch to contrivances for scooping up sand and conveying it to the mouth.

141. Food and digestive system.—In the echinoderms the body-wall is comparatively thin (Fig. 95), and encloses a great space, the body-cavity, in which the digestive and reproductive organs are contained. As the former in various species is adapted for acting upon very different kinds of food, it shows many modifications; but there are a few principal types which may be briefly considered.

In the starfishes the mouth enters almost directly into the cardiac division of the stomach, a capacious, thin-walled sac, much folded and packed away in the disk and bases of the arms (Fig. 95, *b*). This in turn leads into the second pyloric portion (*a*), with thicker walls and dorsal, to the first, from which a short intestine leads to the exterior, near the center of the disk. Another conspicuous and important feature is the so-called liver, consisting of a pair

of closely branched, fluffy glands (*l*), extending the entire length of each arm and opening into the pyloric stomach.

The starfishes are carnivorous and highly voracious, devouring large numbers of barnacles and mollusks which happen in their path. If these are small and free they are taken directly into the stomach, but when one of relatively large size is encountered the starfish settles down upon it, and, slowly pushing the cardiac stomach through the mouth, envelops it in the folds. Digestive fluids are now poured over it, and the victim is speedily despatched and in a partly digested condition is gradually absorbed into the body, leav-

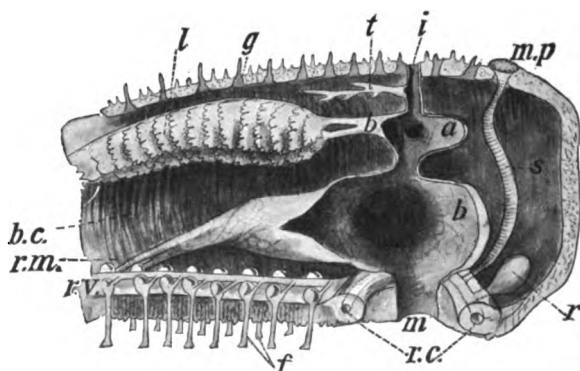


FIG. 95.—Dissection of starfish to show: *a*, pyloric stomach; *b*, bile-ducts (above), cardiac stomach (below); *b.c.*, body-cavity; *f*, feet; *g*, spines; *i*, intestine; *l*, liver; *m*, mouth; *m.p.*, madreporic plate; *r*, reservoir; *r.c.*, ring canal; *r.m.*, stomach retractor muscle; *r.v.*, radial vessel; *s*, stone canal; *t*, respiratory tree.

ing the shell and other indigestible matters upon the exterior. Oysters and clams close their shells when thus attacked, but a steady, continuous pull on the part of the starfish finally opens them, and the stomach is spread over the fleshy portions with speedily fatal results. In the interior of the body the food is transferred to the pyloric stomach, subjected to the action of the liver, and when completely dissolved is borne to all parts of the body.

The digestive system of the starfishes, with its various subdivisions and appendages, is in some respects more complicated than in the other classes. This is most strikingly the case with the serpent-stars, where the entire system for disposing of the minute animals and plants on which it feeds consists of a simple sac communicating with the exterior by a single opening—the mouth.

In the sea-cucumbers large quantities of sand are taken into the body, and the minute organisms and organic matter are digested from it. In the sea-urchins the mouth is provided with five teeth, and the food consists of minute bits of seaweeds, which these snip off. Such diets evidently require a comparatively simple digestive apparatus, for in both it consists throughout its whole extent of a tube of equal caliber, in which the various divisions of esophagus, stomach, and intestine are little, if at all, defined. This is usually somewhat longer than the body, and therefore thrown into several loops; and in the sea-cucumbers its last division is expanded and furnished with more highly muscular walls, which aid in respiration.

142. **Development.**—With but a few exceptions, the eggs of the echinoderms are laid directly in the surrounding water, and for many days the exceedingly minute young are borne great distances in the tidal currents. During this period they show no resemblance to their parents, and only after undergoing remarkable transformations do they assume their permanent features. In every case they have a five-rayed form in early youth, but in several species of starfishes additional arms develop until there may be as many as twenty or thirty.

CHAPTER XIII

THE CHORDATES

143. General characters.—Up to the present time we have been studying the representatives of a vast assemblage of animals whose skeletons, if they have any at all, are located on the outside of the body. In the corals, the mighty company of arthropods, and the echinoderms, it is external. On the other hand, we shall find that the animals we are now about to consider, the fishes, frogs, lizards, birds, and mammals, are in possession of an internal skeleton. In some of the simpler fishes and in a number of more lowly forms (Fig. 96) it is exceedingly simple, and consists merely of a gristle-like rod, the *notochord* (Fig. 98, *nc*), extending the length of the body and serving to support the nervous system, which is always dorsal. This is also the type of skeleton found in the young of the remaining higher animals, but as they grow older the notochord gives way to a more highly developed cartilaginous or bony, jointed skeleton, the vertebral column.

In the young of all these back-boned or chordate animals, the sides of the throat are invariably perforated to form a number of gill-slits. In the lower forms these persist and serve as respiratory organs, but in the higher animals they disappear in the adult. The chordates are thus seen to be distinguished by the possession of a dorsal nervous cord supported by an internal skeleton and by the presence of gill-slits, characters which separate them widely from all invertebrates.

The chordates may be divided into ten classes, seven of

which (the lancelets, lampreys, fishes, amphibians, reptiles, birds, and mammals) are true vertebrates, while the others embrace several peculiar animals of much simpler organization.

144. **The ascidians.**—Among the latter are a number of remarkable species belonging to the class of ascidians or sea-squirts (Fig. 96).

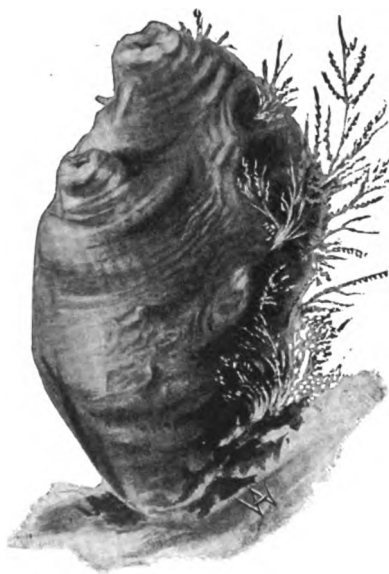


FIG. 96.—Ascidian or sea-squirt.

These are abundantly represented along our coasts, and are readily distinguished by their sac-like bodies, which are often attached at one end to shells or rocks. On the opposite extremity two openings exist, through which a constant stream of water passes, bearing minute organisms serving as food. When disturbed they frequently expel the water from these pores with considerable force, whence the name "sea-squirt."

While many lead solitary lives,

numerous individuals of other species are often closely packed together in a jelly-like pad attached to the rocks, and others not distantly related are fitted to float on the surface of the sea.

The young when hatched resemble small tadpoles both in their shape and in the arrangement of some of the more important systems of organs. For a few hours each swims about, then selecting a suitable spot settles down and adheres for life. From this point on degeneration ensues.

The tail disappears, and with it the notochord and the greater part of the nervous system. The sense-organs vanish, the pharynx becomes remodeled, and numerous other changes occur, leaving the animal in its adult condition, with little in its motionless, sac-like body to remind one of a vertebrate.

145. **The vertebrates.**—Since the remainder of this volume is concerned with the vertebrates it will be well at the outset to gain some knowledge of their more important characteristics. One of the most apparent is the presence of a jointed vertebral column, composed of cartilage or bone, which supports the nervous system. To it are also usually attached several pairs of ribs, two pairs of limbs, either fins, legs, or wings, and in front it terminates in a more or less highly developed skull. In the space partially enclosed by the ribs, the body-cavity, a digestive system is located, which consists of the stomach and intestine, together with the attached liver and pancreas. The circulatory system is also highly organized, and consists of a muscular heart, arteries, and veins which ramify throughout the body. Breathing, in the aquatic animals, is carried on by means of gills, and in the air-breathing forms by means of lungs, which, like the gills, effect the removal of carbonic-acid gas and the absorption of oxygen. The nervous system, consisting of the brain situated in the head and the spinal cord extending through the body above the back-bone, even in the lower vertebrates, is far more complex than in the invertebrates. The sense-organs also attain to a high degree of acuteness, and in connection with the highly organized nervous system enable these forms to lead far more varied and complex lives than in any of the animals heretofore considered.

CHAPTER XIV

THE FISHES

146. **General characters.**—In a general way the name fish is applied to all vertebrates which spend the whole of their life in the water, which undergo no retrograde metamorphosis, and which do not develop fingers or toes. Of other aquatic chordates or vertebrates the ascidians undergo a retrograde metamorphosis, losing the notochord, and with it all semblance of fish-like form. The amphibians, on the other hand, develop jointed limbs with fingers and toes, instead of paired fins with fin rays. A further comparison of the animals called fishes reveals very great differences among them—differences of such extent that they cannot be placed in a single class. At least three great groups or classes must be recognized: the Lancelets, the Lampreys, and the True Fishes. The general characters of all these groups will be better understood after the study of some typical fish, that is one possessing as many fish-like features as possible, unmodified by peculiar habits. Such an example is found in the bass, trout, or perch. In either fish the pointed head is united, without any external sign of a neck, to the smooth, spindle-shaped body, which is thus fitted for easy and rapid cleaving of the water when propelled by the waving of the powerful tail (Fig. 97). A keel also has been provided, enabling the fish to steer true to its course. This consists of folds of skin arising along the middle line of the body, supported by numerous bony spines or cartilaginous

rays. These are the unpaired fins, as distinguished from the paired ones, which correspond to the limbs of the higher vertebrates. In the bass or perch the latter are of much service in swimming, and are also most important organs in directing the course of the fish upward or downward, or for

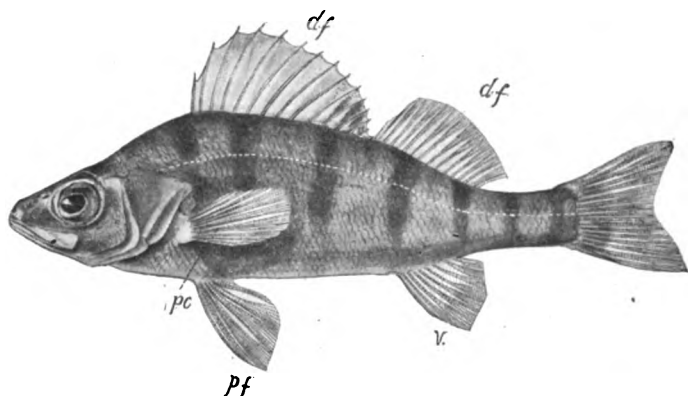


FIG. 97.—Yellow perch (*Perca flavescens*). *df*, dorsal fins; *pc*, pectoral fin; *pf*, pelvic fin; *v*, ventral fin.

aiding the tail in changing the course from side to side; or they may be used to support the animal as it rests upon the bottom in wait for food; and, finally, they may serve to keep the body suspended at a definite point.

In addition to an internal skeleton the bass or perch, like the greater number of fishes, is more or less enclosed and protected by an external one, consisting of a beautifully arranged series of overlapping scales, which afford protection to the underlying organs, and at the same time admit of great freedom of movement. These usually consist of a horny substance, to which lime is sometimes added, and are peculiar modifications of the skin, something like the feathers, nails, and hoofs of higher forms.

147. The air-bladder.—Naturally a fish's body is heavier than the water in which it lives, and there are reasons for thinking that the air-bladder (Fig. 106, *a.bl.*) acts in the

bass and perch and many other fishes as a float to enable them, without much effort, to remain suspended at a definite level. By compressing this sac, partly by its own muscles and partly by those of the body-wall, the bulk of the fish is made less, and it sinks; upon the relaxation of these same muscles the body expands and rises again. Deep-sea fishes, when brought to the surface, where the pressure is relatively slight, are found with their air-bladders so distended that they can not sink again, and the float of surface fishes would be as useless if they were to be carried into the depths below, so that such fishes are compelled to keep within tolerably definite limits of depth. Morphologically considered, the air-bladder is a modified or degenerate lung, and in many fishes it is lost altogether.

148. **Respiration.**—Looking down the throat of the perch, or any other fish, a series of slits (the gill-openings), usually four or five in number, may be seen on each side communicating with the exterior. In the sharks these outer openings are readily seen, but in the bony fishes they open into a chamber on each side of the head, covered by a bony plate or gill-cover that is open behind. On raising these flaps the gills may be seen composed of great numbers of bright-red filaments attached to the bars between each slit. During life the fish may be seen to open its mouth at regular intervals, and, after gulping in a quantity of water, to close it again, contracting the sides of the throat to force it out of the gill-openings and over the gill-filaments to the exterior. During this process the blood traversing the excessively thin filaments extracts the oxygen from the water and carries it to other parts of the body.

With this information, let us return to the study of the three classes of fishes.

149. **The lancelet (*Branchiostoma*).**—The lancelet, sometimes called amphioxus (Fig. 98), the type of the class *Leptocardii*, is a little creature, half an inch to four inches long, in the different species, transparent and colorless, living in the

sand in warm seas, the nine species known being found in as many different regions. A lancelet may be regarded as a vertebrate reduced to its lowest terms. Instead of a jointed back-bone, it has a cartilaginous notochord, running from the head to the tail. A nervous cord lies above it, enclosed in a membranous sheath. No skull is present, and the nerve-cord does not swell into a brain. There are no eyes and no scales. The mouth is a vertical slit, without jaws. There is no trace of the shoulder-girdle (shoulder-blade and collar-bone) or pelvis (hip-bone) from which

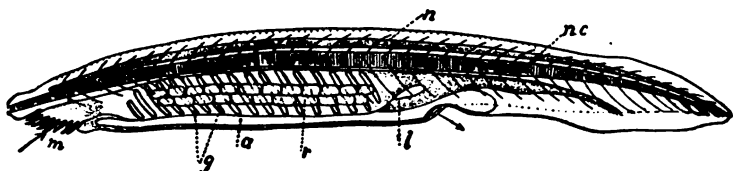


FIG. 98.—The California lancelet (*Branchiostoma californiense*). Twice the natural size. *g*, gills; *l*, liver; *m*, mouth; *n*, nerve-cord; *nc*, notochord.

spring the paired fins, which, in true fishes, correspond to arms and legs. The circulatory system is fish-like, but there is no heart, the blood being driven about by the contraction of the walls of the vessels. Along the edge of the back and tail is a rudimentary fin, made of fin-rays connected by membrane. In the character and arrangement of its organs the lancelet is certainly like a fish, but in degree of development it differs more from the lowest fish than the fish does from a mammal.

150. Lampreys (or Cyclostomes).—The class of lampreys stands next in development (Fig. 99). The notochord gives way anteriorly to a cartilaginous skull, in which is contained the brain, of the ordinary fish type. There are eyes, and the heart is developed, and consists of an auricle and a ventricle. As distinguished from the true fish, the lampreys show no trace whatever of limbs or of the bones which would support them. The lower jaw is wholly wanting, the mouth being a roundish sucking disk. The fins

are better developed, but of the same structure as in the lancelet. There is no bony matter in the skeleton, and there are no scales. The nasal opening is single on the top of the front of the head.

There are about twenty-five species in this class. Some of them, called lampreys, ascend the streams from the sea



FIG. 99.—Lampreys.

in the spring for the purpose of spawning. The young undergo a metamorphosis, at first being blind and toothless. The adults feed mostly on the blood of fishes, which they suck after scraping a hole in the flesh with their rasp-like teeth. The others, called hag-fishes, live in the sea and bore into the bodies of other fishes, whose muscles they devour. All are slender, smooth, and eel-shaped.

From their structure and a few fossil remains we suppose that these eel-like forms existed long ago, probably before the more highly developed sharks and bony fishes made their appearance, but it is difficult to determine whether their simple organization is of such long standing or is not in part the result of semiparasitic habits, or a life spent

largely in burrowing. Like the lancelet and other simple chordates, they are of the greatest interest to the zoologist who gains from them some idea of the lowly vertebrate forms that peopled the earth long ago.

151. True fishes.—The third class, Pisces or true fishes, to which the shark as well as the bass and perch belong has a well-developed skeleton, skull, and brain. The lower jaw is developed, forming a distinct mouth, and there is at least a shoulder-girdle and pelvis; although the fins these should bear are not always developed, the general traits are those we associate with the fish. Of the true fishes, there are again several strongly marked groups, usually called subclasses. Of these, three chiefly interest us.

152. The sharks and skates.—Very early in the life of the sharks (Fig. 100) and skates (*Selachii* or *Elasmobranchii*)

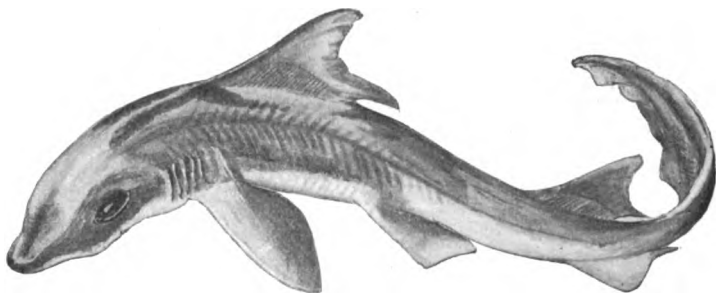


FIG. 100. —Young shark (*Galeus zyopterus*). One-seventh natural size.

a notochord appears, similar to that in the lancelet and the lampreys. As growth proceeds its sheath becomes broken up into a series of cartilaginous rings, which thus appear like spools strung on a cord. As the fish grows older these "spools" or vertebrae grow solid, cutting the notochord into little disks, and great flexibility is thus secured. Cartilaginous appendages also grow up and cover the spinal nerve-cord lying above, and give strength to the unpaired fins; the paired fins also have their supports. The shoulder-

girdle is placed behind the skull, leaving room for a distinct neck ; strong bars of cartilage bear the gills ; others form jaws to carry the teeth ; and a complex skull protects the brain and sense-organs, which are of a relatively high state of development. Throughout life the skeleton is of cartilage, with perhaps here and there a little bone where greater strength is required. Besides these, there are numerous minor characters which the student will readily find for himself.

The sharks and skates or rays live chiefly in the sea, and some reach an enormous size, the largest of all fishes. Some are very ferocious and voracious ; others are very mild and weak, and the development of teeth is in direct proportion to their voracity of habit. In earlier geologic times there were many more species of them than now exist.

153. The lung-fishes.—The lung-fishes (Dipnoi) are peculiar forms living in some of the rivers of Australia and the tropical regions of Africa and South America. In these the air-bladder is developed as a perfect lung. During the wet season they breathe like other fishes by means of gills, but as the rivers dry up they burrow into the wet mud and breathe by means of lungs which are spongy sacs of which the air-bladder of other fishes is a degenerate representative. As we shall see, they resemble in this respect the tadpoles and some adult Amphibia (frogs and salamanders). The paired fins are also peculiar in structure, having an elongate jointed axis, with a fringe of rays along its length, a structure almost as much like that of the limbs of a frog as that of a fish's fin. In fact the Dipnoi must be regarded as an ancestral type, an ally of the generalized form from which Amphibia and bony fishes have descended. Only four living species of dipnoans are known, but great numbers of fossil species are found in the rocks.

154. The bony fishes (Teleostei).—The bony fishes, or Teleosts, are distinguished by the bony skeleton, the symmetrical tail, and by the development of the air-bladder as a more or less completely closed sac, useless in respiration.

Often this organ is altogether wanting, as in the common mackerel. About ten thousand kinds of bony fishes are known. The species swarm in every sea, lake, or river throughout the earth, and some form or another among them is familiar to every boy in the land. These fishes are divided into about two hundred families, and these may be arranged in fifteen to twenty orders. As these are mostly distinguished by features of the skeleton, we need not name them here. In Jordan and Evermann's *Fishes of North and Middle America*, as well as in various other books, the student of fishes can find the characters by which orders may be distinguished.

155. **Sturgeons and garpikes (Ganoidea).**—While the great majority of the typical fishes possess a bony skeleton, there are a few quaint types—the ganoid fishes, such as the sturgeons (Fig. 101) and garpikes—in which it is cartilaginous or partly bony. In past ages these were probably the highest type of fishes, and from their fossil remains we may conclude that they flourished in vast numbers; but at present they are almost extinct. In this country the ganoids are represented by several species, the best known being the sturgeons which inhabit the Great Lakes, the Mississippi, and its tributaries; while on the East coast the common sturgeon (*Acipenser sturio*) often leaves the sea and ascends rivers. They are the largest fishes found in fresh water, attaining a length of ten or twelve feet, and a weight of five hundred pounds. Their food consists of small plants and animals, which they suck in through their tube-like mouth. The garpikes live in the larger lakes and rivers throughout the East and Mississippi Valley. Their bodies, from three to ten feet in length, according to the species, are covered with comparatively large regularly arranged square scales, and the upper jaw is elongated to form a kind of beak, abundantly supplied with teeth. They are carnivorous, voracious fishes, working great havoc among the more defenseless food-fishes.

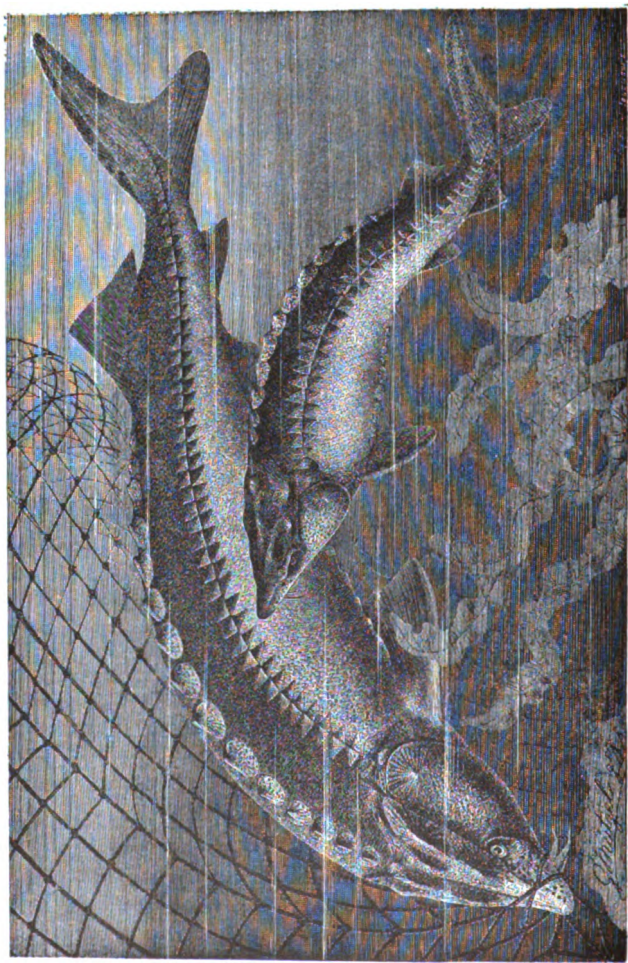


FIG. 101.—Russian sturgeon (*Acipenser hus*).—After Brehm.

156. The catfishes.—Among the lowest bony fishes we may place the great group to which almost all fresh-water fishes belong. In this group the four vertebræ situated next the head are firmly united, and by means of certain small lever-like bones a connection is formed between the air-bladder and the ear of the fish, which is sunk deep in the skull. The air-bladder thus becomes a sounding organ in the function of hearing. The family of catfishes possesses this structure, and the student should look for it in the first one he catches. The catfishes are remarkable for the long feelers about the mouth, with which they pick their way on the bottom of a pond. There are many kinds the world over. The small ones are known as horned pout or bullhead. In these the dorsal and pectoral fins are armed each with a strong, sharp spine, which is set stiff when the fish is disturbed, and makes them very troublesome to handle. The catfishes have no scales.

157. The carp-like fishes.—The still greater carp family includes all the carp, dace, minnows, and chubs. They have the air-bladder joined to the ear, just like the catfish, but they lack the long feelers and the fin spines, while the soft body is covered with scales, and there are no teeth in the mouth. In the throat are a few very large teeth, which the ingenious boy should find. In the sucker family these throat teeth are like the teeth of a comb, and the mouth is fitted for sucking small objects on the river bottom.

158. The eels.—In the great order of eels the body is long and slim, scaleless, or nearly so, with no ventral fins. The shoulder-girdle has slipped back from the head, so as to leave a distinct neck, while ordinary fishes have none. Of eels there are very many kinds—some large and fierce, some small as an earthworm; and one kind comes into fresh water. a sp.

159. Herring and salmon.—In the great order which includes the herring and salmon the vertebræ are all alike, the ventral fins far from the head, and the scales smooth to

the touch. The herring and shad are examples, as also the salmon and trout. Some live in the great depths of the sea, even five miles below the surface. These are very soft in body, being under tremendous pressure. They are inky black—for the sea at that depth seems black as ink—and most of them have luminous spots which give them light in the darkness. Some species have the forehead luminous, like the headlight of an engine. Most of these deep-sea fishes are very voracious, for there is nothing for them to feed on save their neighbors.

160. The pike, sticklebacks, etc.—Several small orders stand between these soft-rayed, smooth-scaled fishes and

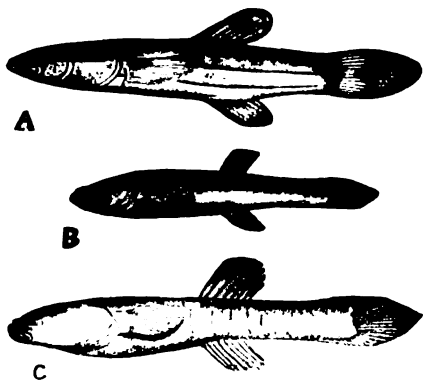


FIG. 102.—The blindfish and its parentage. A, Dismal Swamp fish (*Chologaster arilus*), the ancestor of (B) Agassiz's cave fish (*Chologaster agassizi*) and (C) cave blindfish (*Typhlichthys subterraneus*).

the form, like the perch and bass, which has many spines in the dorsal fin. Among these transitional forms is the pike (Fig. 103)—long, slender, circumspect, and voracious, lying in wait under a lily-pad; the blindfish, which lost its eyes through long living in the streams of the great caves; the stickleback, small, wiry, malicious, and destructive, stealing the eggs and nibbling the fins of any larger fish; the sea-horse, often clinging with its tail to floating

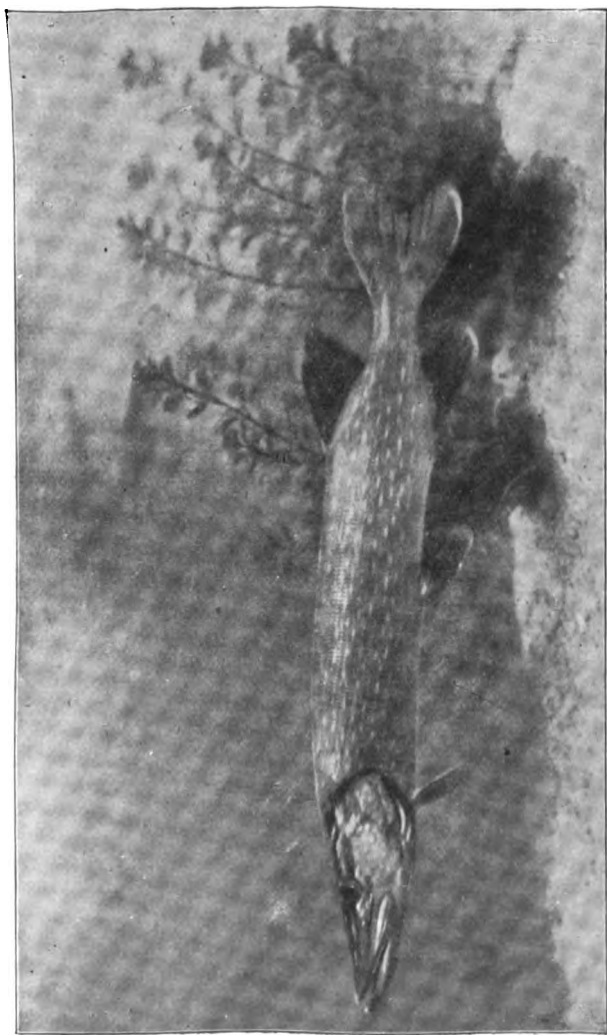


FIG. 103.—The pike (*Esox*). From photograph by R. W. SHUFFELDT.

seaweed, the male carrying the eggs about in his pocket until they hatch; the mullet, stupid, blundering, feeding on minute plants, crushing them in a gizzard like that of a hen, but withal having soft flesh, good for the table; the flying-fishes, which sail through the air with great swiftness to escape their enemies.

161. **The spiny-rayed fishes.**—In the group of spiny-rayed fishes the ventral fins are brought forward and joined to the shoulder-girdle. The scales are generally rough to the touch, and the head is usually roughened, also. There are many in every sea, ranging in size from the Everglade perch of Florida, an inch long, to the swordfish, which is thirty. These are the most specialized, the most fish-like of all the fishes. Leading families are the perch, in the fresh waters, the common yellow perch, familiar to all boys in the Northeastern States; the darters, which are dwarf perches, beautifully colored and gracefully formed, living on the bottoms of swift rivers; the sunfishes, with broad bodies and shining scales, thriving and nest-building in the quiet eddies; the sea-bass of many kinds, all valued for the table; the mackerel tribe, mostly swimming in great schools from shore to shore. After these come the multitude of snappers, grunts, weakfishes, bluefishes, rose-fishes, valued as food. Then follow the gurnards, with bony heads; the sculpins, with heads armed with thorns, the small ones in the rivers most destructive to the eggs of trout; and at the end of the long series a few families in which the spines once developed are lost again, and the fins have only soft and jointed rays. It is a curious law of development that when a structure is once highly specialized it may lose its usefulness, at which point degeneration at once sets in. Among fishes of this type are the cod-fishes, with spindle-shaped bodies, and the flounders, with flat bodies. The flounders lie on the sand with one side down, and the head is so twisted that the eyes come out together on the side that lies uppermost. This side is col-

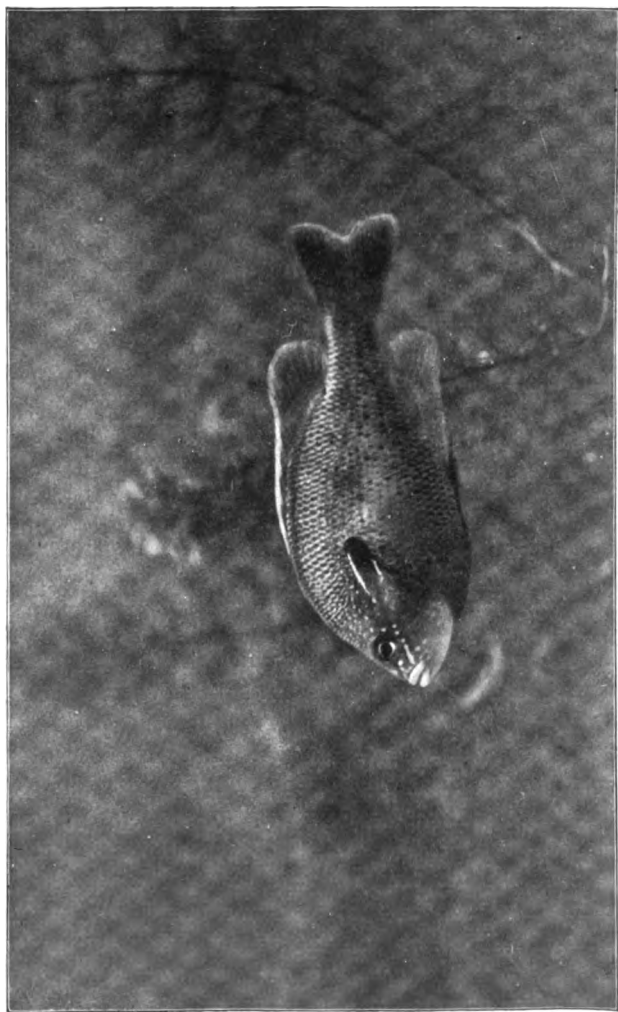


FIG. 104.—Long-eared sunfish (*Lepomis megaloche*).—From photograph by R. W. SHUFELDT.

ored like the bottom—sand colored or brown or black—and the under side is white. When the flounder is first hatched, the eyes are on each side of the head, and the animal swims upright in the water like other fishes. But it soon rests on the bottom; it turns to one side, and as the body is turned over the lower eye begins to move over to the other side. Finally, we may close the series with the anglers (Fig. 105), in which the first dorsal spine is transformed into a sort of fishing-pole with a bait at the end, which may sometimes serve to lure the little fishes, which are soon swallowed when once in reach of the capacious mouth.

162. Internal anatomy.—A few fishes are vegetarians, but the greater number are carnivorous. Some swallow large quantities of sand of the sea-bottom and absorb from it the small organisms living there. Others are provided with beaks for nipping off corals and tube-dwelling worms. Huge plate-like teeth enable others to crush mollusks, sea-urchins, and crabs, and many are adapted for preying upon other fishes. The latter are often able to escape, owing to the presence of numerous spines, sometimes supplied with poison-glands; or their colors are protective, and a vast number of devices are present which enable them with some degree of surety to escape their enemies and capture food.

Usually, without mastication, the food passes into the digestive tract (Fig. 106), which in the main resembles that of the squirrel, but varies considerably according to the nature of the food it is required to absorb. As in other animals, it is usually longer in the vegetable feeders. In most fishes the walls of the canal are pushed out at the junction of the stomach and intestine, to form numerous processes like so many glove-fingers (the pyloric cœca, Fig 106, *py.c.*), which probably serve to increase the absorptive surface. The same result is obtained in other ways, chiefly by numerous folds of the lining of the canal.

The blood-system is much more complex in the fishes

than in any of the invertebrates. It also differs in its general plan from that of most adult vertebrates, owing to the peculiar method of respiration. In almost every case the

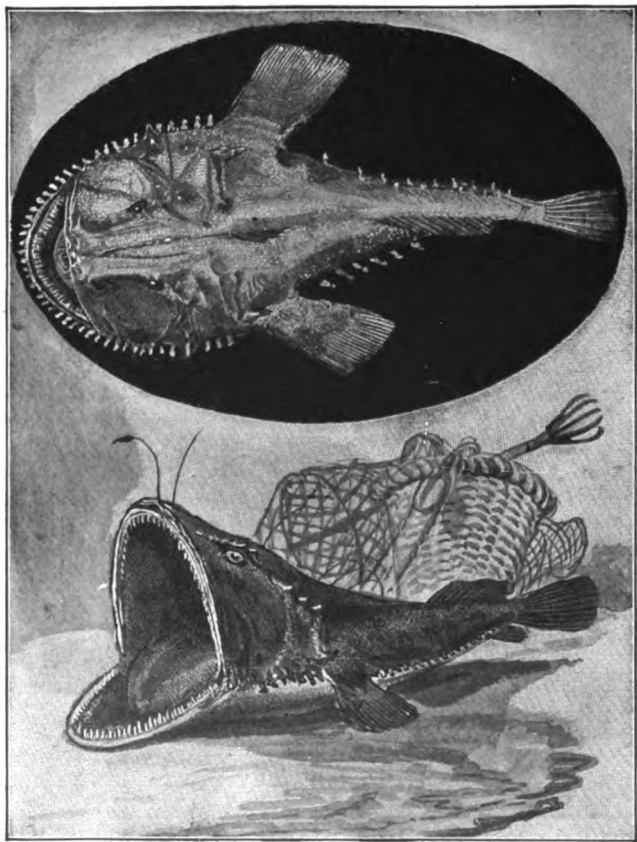


FIG. 105.—Angler or frogfish (*Lophius piscatorius*). One-tenth natural size.—After BASKETT.

vessels returning from all parts of the body unite into one vein leading into the heart, which consists of only one auricle and ventricle (Fig. 106). From the heart the blood

is forced through the gills, with all their delicate filaments, and now, laden with oxygen and nutritious substances already absorbed from the coats of the digestive tract, it

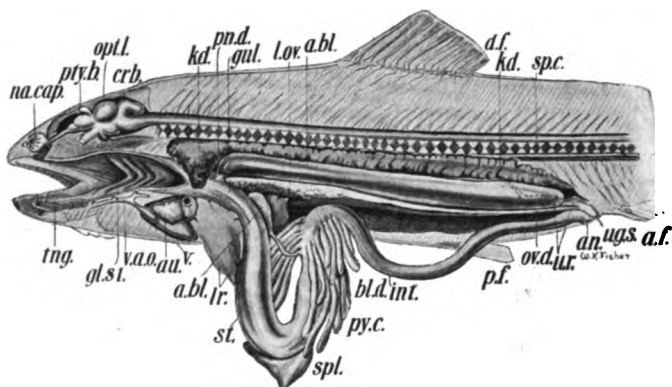


FIG. 106.—Dissection of a bony fish, the trout (*Salmo*). *a.bl.*, air-bladder; *an.*, anal opening; *au.*, auricle; *gl.st.*, gills; *gul.*, esophagus; *int.*, intestine; *kd.*, kidney; *lr.*, liver; *lov.*, ovary; *opt.l.*, brain; *py.c.*, pyloric caeca; *spc.*, spinal cord; *spl.*, spleen; *st.*, stomach; *v.*, ventricle.

travels on to all parts of the body, continually unloading its cargo in needy districts and waste matters in the kidneys before returning once more to the heart.

163. **The senses of fishes.**—The habits of fishes indicate that they know considerable of what is going on in the outside world, and their well-developed sense-organs show the degree of their sensitiveness. A share of this information comes through the sense of touch, which is distributed all over the surface of the body, chiefly in the more exposed regions sometimes especially provided with fleshy feelers, like those on the chin of the catfish.

The sense of smell appears to be fairly developed, as is that of hearing; but there is no evidence of a sense of taste. A few fishes chew their food, and may possibly taste it, but there are others that swallow it whole, and in all there are relatively a few nerves going to the tongue or floor of the mouth.

The eyes of most fishes are highly developed, and are of the greatest use at all times. Exceptions to the rule are found in certain species which live in caves or in the dark abysses of the ocean. In some of these the eyes have disappeared almost completely, and the sense of touch becomes correspondingly more acute; in other deep-sea forms they have grown to a large size, enabling them to distinguish objects in the gloom, like the owls and other nocturnal animals. Embedded in the skin of some of these deep-sea fishes, and certain nocturnal ones, are peculiar spots, composed of a glandular substance, which produces a bright glow like that of the fireflies. These may be located on the head or arranged in patterns over various parts of the body, and may serve to light the fish on its way and enable it to see its food to better advantage, or it may act as a lure to many fishes that become victims to their own curiosity. In those fishes which are active most of the time the eyes are located on the sides of the head, and in those which remain at or near the bottom they are turned toward the top; in every case where they can be used to the best advantage.

164. Breeding habits.—Fishes usually lay their eggs in spring, the salmon-trout and others in the winter. In breeding-time the males often grow resplendent, and may engage in struggles for their respective mates. In others this ceremony is performed without show of hostility. Some make nests, while others lay their eggs loosely in the water.

In all the salmon family the young fishes are born in the colder fresh-water rivers, and later make their way into the sea, where they spend the greater part of their lives. When the time comes for them to lay their eggs they migrate in great companies, and make their way hundreds, perhaps thousands, of miles to the rivers in which they spent their youth. Up these streams they rush in crowds, leaping waterfalls and rapids, and, dashed and battered on the rocks, many, and in some species all, die from injuries

or exhaustion after the breeding season is passed. The eggs, like those of the chubs, suckers, sunfishes, and catfishes, are usually buried in shallow holes in the sand, and the males of most fishes keep a faithful watch over the young until they are able to live in safety. In some of the sticklebacks and several marine species elaborate nests are composed of grass or seaweeds; some of the catfishes carry the eggs until they hatch in their mouths or else in folds of spongy skin on the under side of the body; in the pipefishes and sea-horses a slender sac along the lower surface of the male acts as a brood-pouch, in which the female places the eggs to remain until developed; and some fishes, such as the surf-fishes and a number of the sharks, bring forth their young alive. On the other hand, the young of many of the herrings, salmon, cod, perch, and numerous other fishes are abandoned at their birth, and fall a prey to many animals, even their parents often included.

In the former cases, where the young are protected, only a relatively few eggs are produced: where they are abandoned the female often lays many millions. In every case the number of eggs is in direct relation to the chances the young have of reaching maturity, a few out of each brood surviving to perpetuate the race.

165. Development and past history.—The eggs of the higher bony fishes are usually small (one-tenth to one-third of an inch in diameter), and the young when they hatch are accordingly little; in the sharks the eggs are larger, the size of a hen's egg or even larger, and the young when born are relatively large and powerful. These differences, however, do not greatly affect the early development, for in every case the head and then the trunk soon become formed, gills arise, the nervous system appears, which is invariably supported by a skeleton in the form of a gristly rod—the notochord. In the lower forms of fishes this persists throughout life; but in the sharks and skates it becomes replaced in the adult by another and higher type of

skeleton, which is much more specialized with the bony fishes.

Those who study the fossils on the rocks tell us that the first fishes were very simple, and many believe that their skeleton, like that of the little growing fish, consisted only of a notochord. Many of these old forms died out long ago, while others gradually changed in one way and another to adapt themselves to their surroundings, the constant need of adaptation having resulted in the multitude of present-day types. Some, such as the lamprey, have probably changed relatively only to a slight extent; others, like the sharks and skates, are much more altered; and the bony fishes are far from their original low estate, though their development has been rather toward a greater specialization for aquatic life than an advance upward. The little fish in its growth from the egg thus repeats the history of its ancestral development; but as though in haste to reach the adult condition, it omits many important details. Moreover, the record in the rocks is not complete, and we have many things yet to learn of the ancient fishes and their development from age to age to the present day.

CHAPTER XV

THE AMPHIBIANS

IN many respects the amphibians—toads, frogs, and salamanders—resemble the fishes, especially the lung-fishes (Dipnoi). The modern amphibians are essentially fishes in their early life, but in developing legs and otherwise changing their bodily form they become adapted for a life on land under conditions differing from those of the fishes. Judging from this class of facts, we may assume that fish-like ancestors, by the development of the lungs, became fitted for a life on land, and that from these the amphibians of our times have been derived.

166. **Development.**—The eggs of the Amphibia are laid during the spring months in fresh-water streams and ponds. They are globular, about as large as shot, and are embedded in a gelatinous envelope (Fig. 107). They are either deposited singly or in clumps, or festooned in long strings over the water-weeds. During the next few days development proceeds rapidly under favorable conditions, resulting in an elongated body with simple head and tail. In this condition they are hatched as tadpoles. As yet they are blind and mouthless, but lips and horny jaws soon appear, along with highly developed eyes, ears, and nose. External fluffy gills arise on the sides of the head, and slits form in the walls of the throat, between which gills are attached, and over which folds of skin develop, as in the fishes. A fin-fold like that of the lancelet or lamprey appears on the tail. The brain and spinal cord, extending along the line of the back, are supported by a gristly notochord, and complete and com-

plex internal organs adapt the animal to a free-swimming existence for days to come.

The tadpole is now, to all intents and purposes, a fish—a fact most clearly recognized in its form, method of loco-



FIG. 107.—Metamorphosis of the toad.—Partly after GAER, from *Animal Life*.

motion, the arrangement of the gills, and the general plan of the circulatory system.

167. Further growth.—In the course of the next few weeks hind limbs develop beneath the skin, through which they finally protrude. In the same manner, fore limbs arise at a later date. In position these organs are like the paired fins of fishes, but they are intended for crawling or leaping on land, and are modified in accordance with this need. As in the higher vertebrates, the limbs develop as arms and legs, with long fingers and toes, between which are stretched webs of skin, which serve in swimming.

In the meantime large internal changes are also taking place. The wall of the esophagus has gradually pouched out to form the lungs. They are richly supplied with blood-vessels, closely resembling in their general features the lungs of the lung-fishes. The animal now rises to the surface occasionally to gulp in air, and it also continues to breathe by means of gills. At this stage of its existence, therefore, the larva is amphibious (two-living), and we have the interesting example of an animal extracting oxygen from both the water and the air. The diet of the tadpole at this time changes from vegetable to animal substances, and horny teeth give way to the small teeth of the frog, and the digestive system undergoes an entire remodeling to adapt it to its new duties. The young amphibian—whether frog, toad, or salamander—is now a four-legged creature, with well-developed head and tail, with lungs and gills, though the latter are usually fast disappearing, and is rapidly assuming those characters which will fit it for a terrestrial or semiaquatic existence.

168. **The salamanders.**—The changes which now ensue in such a larva in reaching the adult condition are relatively slight in the lower salamanders. The external gills often persist (Fig. 110), the lungs are also functional, and the changes are largely those of increase of size. In the larger number of species the gills disappear more or less completely (Fig. 108), such species often abandoning the water for homes in damp soil or under stones and logs, returning to it only when the time comes for their eggs to be laid. The limbs are always relatively weak, never supporting the body from the ground, but serving in a clumsy way to push it from place to place. In the aquatic forms the tail continues to serve as a swimming organ. In some species the hind legs become rudimentary, or even entirely lacking. A still further modification occurs in a few burrowing species, which move by wrigglings of the body, and are without either pairs of legs.

In geological times many of the salamanders were of great size, several feet in length, and some were enclosed in an armor consisting of bony plates. All now living have the skin naked, and with the exception of the giant species of Japan, three feet in length, and a few similar forms in America, the modern representatives are comparatively



FIG. 108.—Blunt-nosed salamander (*Amblystoma opacum*). Photograph by W. H. FISHER.

feeble and measure their length by inches. Only a few, on account of their bright colors, are particularly attractive, while the others are usually shunned and considered repulsive, chiefly because of their supposed poisonous character, though in reality few animals are more harmless.

169. **Tailless forms.**—In the frogs and toads the metamorphosis which the young undergo is almost as profound as that which takes place with the insects. The gills, together with their blood-vessels, disappear completely. The tail, with its muscles, nerve-supply, and skeleton, is absorbed. The cartilaginous notochord gives way to a jointed back-bone. A skull is developed; numerous bones form in the limbs, affording an attachment for the powerful muscles which make the toad, and especially the frog, expert swim-

mers and leapers, and thus equipped they hereafter lead a wholly terrestrial or semiaquatic life.

170. Distribution and common forms.—All the Amphibia are dependent upon moisture. Almost all are hatched and developed in fresh water, and those which leave the water return to it during the breeding season. So we find representatives of the group all over the world having much the same range as the fresh-water fishes. The great majority of the salamanders are confined to the northern hemisphere, but the toads and frogs are almost universally distributed.

Among the salamanders in this country only a relatively few species completely retain their external gills. This is the case with sirens and mud-puppies or water-dogs (Fig. 110), which may occasionally be seen in the clear waters of our lakes and rivers crawling slowly about in search of food, and every now and then rising to the surface to gulp in air. The remainder lose their gills more or less completely, and usually leave the water for damp haunts on land. One of the blunt-nosed salamanders, known as the tiger salamander (*Amblystoma tigrinum*), is found in moist localities in most parts of the United States. Besides these are numerous small species, among them the newts (*Desmognathus*), ranging widely over the United States, living under logs and stones and feeding upon the small insects and worms inhabiting such situations. In several species of salamanders the lungs disappear with age, and respiration is performed solely through the surface of the skin.

The tailless amphibians are much more abundant and familiar objects than the salamanders, and from the opening of spring until late in the fall they are met with on every hand. With few exceptions the frogs live in or about ponds and marshes, in which they obtain protection in troublous times and from which they derive the store of worms and insects that serve as food. On the other hand, the tree-frogs, as their name indicates, usually abandon the water and repair to moist situations in trees and other vege-

tation. Their shrill, cricket-like calls are often heard in the summer. The fingers and toes are more or less dilated into disks at their tips, enabling them to climb with considerable facility; and they are further adapted to their surroundings on account of their protective colors. The toads undergo their metamorphosis while very small, and approach the water only at the breeding season. During the day they remain concealed in holes and crevices, but at the approach of evening come out in search of food.

171. **Means of defense.**—The food of the members of this group consists chiefly of small fishes, insect larvæ, snails, and little crustaceans, which are swallowed whole. On the other hand, many Amphibia prey on each other, while most of them are eagerly sought by birds and fishes. Some, as the toads, stalk their food only during the night-time or depend upon their agility to escape their enemies. Others are colored protectively, the markings of the skin resembling the foliage of the earth upon which they rest, and in some species, as the tree-toads, this color-pattern changes as the animal shifts its position. A few species are most brilliantly colored with red, green, yellow, or combinations of these, in striking contrast to their surroundings. They have apparently few enemies, possibly because of an unpleasant odor or taste, and it has been suggested that their gorgeous tints are danger-signals, warning their would-be captors from attempting a second time to devour them. At the same time it is well known that the somber-hued toads emit a milky secretion from the warty protuberance of their skin which is intensely bitter, irritating to delicate skin, and poisonous to several animals.

172. **Skeleton.**—As in all vertebrates, the skeleton of the amphibian first arises as a cartilaginous rod, the notochord, which is afterward replaced by a jointed back-bone, to which the limbs are attached. The back-bone is anteriorly modified into a flat, usually complex, skull. In the salamanders the number of vertebræ is sometimes very large,

and the body correspondingly long and snake-like; but in other cases parts of the vertebræ are reduced in number, and the body is rather short and thick. In the frogs and toads this reduction reaches its culmination, for only nine distinct vertebræ are present, the tail vertebræ, corresponding to those of the salamanders, being represented by a rod-like bone, the urostyle, made of segments grown together.

173. **Digestive and other systems.**—In its main characters the digestive tract of the amphibian (Fig. 109) resembles

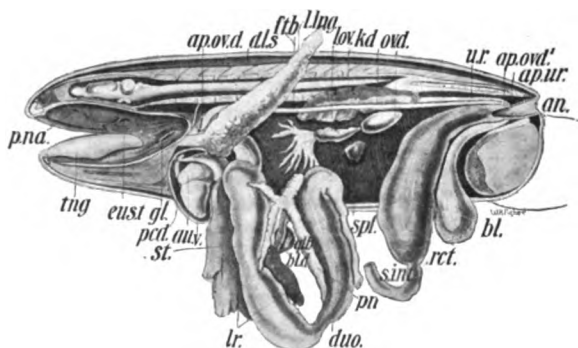


FIG. 109.—Dissection of toad (*Bufo*). *an.*, anal opening; *av.*, auricle; *bl.*, bladder; *duo.*, duodenum; *lng.*, lung; *lr.*, liver; *pn.*, pancreas; *rect.*, rectum; *spl.*, spleen; *st.*, stomach; *v.*, ventricle.

that of the fishes and the squirrel. The mouth is usually large, and the teeth are very small, as in the frog or salamander, or are lacking completely, as in the common toad. In many salamanders the tongue, like that of a fish, is fixed and incapable of movement. In most of the frogs and toads it is attached to the front of the mouth, leaving its hinder portion free, and capable of being thrown over and outward for a considerable distance. In the throat region gill-clefts may persist, but they usually close as the lungs reach their development. The succeeding portions of the canal are comparatively straight in the elongated forms, or

more or less coiled in the shorter species. In some cases no well-marked stomach exists, but ordinarily the different portions, as they are shown in Fig. 109, are well defined.

As noted above, the circulation in the tadpole is the same as in fishes, then lungs arise, and for a time respiration is effected both by gills and lungs, and the circulation resembles in its essential points that of the lung-fishes. This may continue throughout life, but more frequently the gills and their vessels disappear, and the circulation approaches that of the reptiles. In such forms the heart consists of two auricles and one ventricle. Into the left auricle pours the pure blood from the lungs; into the right the impure blood from the body. To some extent these mix as they are forced into the general circulation by the single ventricle. The amount of oxygen carried is therefore smaller than in the higher air-breathers, the amount of energy is proportionately less, and hence it is that all are cold-blooded and of comparatively sluggish habits.

In some species of salamanders the lungs may also disappear, and breathing is carried on by the skin, as it is to a certain extent in all amphibians. In the frogs and toads lungs are invariably present, and vocal organs are situated at the opening of the windpipe in the throat. These produce the characteristic croaking and shrilling, which in many species are intensified through the agency of one or two large sacs communicating with the mouth-cavity.

Although the brain is small in the amphibians, it is more complex in several respects than it is in fishes. The eyes are also usually well developed, but in some of the cave and burrowing salamanders they are concealed beneath the skin, and are rudimentary. The ear varies considerably in complexity in the different species, but in the possession of semicircular canals and labyrinth resembles that of the fishes. In the frogs and toads, as one may readily discover, the drum or tympanum is external, ap-

pearing as a smooth circular area behind the eye. Organs of touch, smell, and taste are likewise developed in varying degree of perfection.

174. **Breeding-habits.**—While the great majority of amphibians mate in the spring and deposit their eggs in the water, often to the accompaniments of croakings and pipings almost deafening in intensity, several species, for various reasons, have adopted different methods. Some of the salamanders bring forth young alive, and several species of toads and frogs are known in which the young are cared for by the parent until their metamorphosis is complete. In one of the European toads (*Alytes*) the male winds the strings of eggs about his body until the tadpoles are

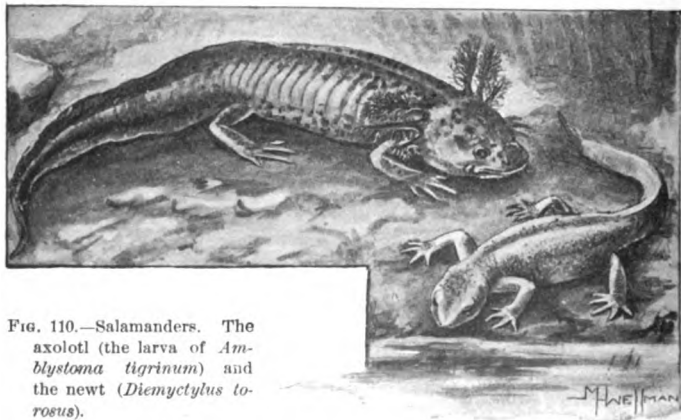


FIG. 110.—Salamanders. The axolotl (the larva of *Ambystoma tigrinum*) and the newt (*Diemyctylus torosus*).

ready to hatch ; and in a few species of tree-toads the eggs are stored in a great pouch on the back of the parent until the early stages of growth are over. In the Surinam toad of South America the eggs are placed by the male on the back of the female, and each sinks into a cavity in the spongy skin. Here they pass through the tadpole stage without the usual attendant dangers, and emerge with the form of the adult.

Sunlight and warmth are apparent necessities for speedy development. Tadpoles kept in captivity where the conditions are generally unfavorable may require years to assume the adult form. As mentioned above, the tiger salamander (*Amblystoma tigrinum*) occurs in most parts of the United States and Mexico. In the East this species drops its gills in early life as other salamanders do, and assumes the adult form, but in the cold water of high mountain lakes, in Colorado and neighboring States, it may never become adult, always remaining as in Fig. 110. This peculiar form is locally known as axolotl. In this condition it breeds. It is thus one of the very few examples of animals whose undeveloped larvæ are able to produce their kind. Owing to this trait it was at first considered a distinct species, and many years elapsed before its relationship to the true adult form was discovered.

CHAPTER XVI

THE REPTILES

175. General characteristics.—In all the reptiles the general shape of the body, and to some extent the internal plan, is not materially different from that seen among the amphibians. In spite of external resemblance the actual relationship is not very close. It appears to be true that ages ago the ancestors of the modern reptiles were aquatic animals, possibly somewhat similar to some of the salamanders; but they have become greatly changed, and are now, strictly speaking, land animals. At no time in their development after leaving the egg do we find them living in the water and breathing by gills. Some species, such as the turtles, lead aquatic or semiaquatic lives, but the modifications which fit them for such an existence render them only slightly different from their land-inhabiting relatives. The skin bears overlapping scales or horny plates, united edge to edge, as in the turtles, enabling them to withstand the attacks of enemies and the effects of heat and dryness. Indeed, it is when heat is greatest that reptiles are most active. In no other class of vertebrates, and very few invertebrates, do normal activities of the body appear to be so directly dependent upon external warmth. In the presence of cold they rapidly grow sluggish, and sink into a dormant state.

As in the case of all animals, habits depend upon structure, and accordingly among the reptiles we find many remarkable modifications, enabling them to lead

widely different lives. Nevertheless all are constructed upon much the same plan.

176. **The lizards (Sauria).**—As in the amphibians, especially the salamanders, the body (Fig. 111) consists of a relatively small head united by a neck to the trunk,



FIG. 111.—Common lizard or swift (*Sceloporus undulatus*). Photograph by W. H. FISHER.

which, in turn, passes insensibly into a tail, usually of considerable length. Two pairs of limbs are almost always present, and these exhibit the same skeletal structure as in the amphibians; but in their construction, as in the other divisions of the body, we note a grace of proportion and muscular development which enable the lizards to execute their movements with an almost lightning-like rapidity. The mouth is large and slit-like, well armed with teeth, and the eyes and ears are keen. Scales of various

forms and sizes, always of definite arrangement, cover the body. The scales are always colored, in some species as brilliantly as the feathers of birds, and usually harmonize with the surroundings of the animal, enabling it to escape the attacks of its many enemies. Altogether the lizards are a very attractive group of animals. As in the salamanders, the vertebral column is usually of considerable length, but it too presents a lighter appearance and a greater flexibility. Slender ribs are present, and a breast-bone and the girdles which support the limbs. Although more ossified than in the amphibians, the skull still continues to be composed here and there of cartilage. The roof also is yet incomplete, but with the firm plates on the surface of the head ample protection is afforded the small brain underneath. As above mentioned, the limbs are slender and insufficient to support the body, which accordingly rests upon the ground, and by its wriggings and the pushing of the limbs is borne from place to place. It will be recalled that some of the salamanders living in subterranean haunts and burrowing in the soil have no need of limbs, and the latter have accordingly disappeared. This condition is paralleled by certain species of lizards. The blindworms (which are neither blind nor worms, but true lizards, though snake-like in appearance) are devoid of limbs, as are also the "glass-snakes." In some species the hinder pair arise in early life, but they remain small, and ultimately disappear. In almost all lizards the tail is very brittle, breaking at a slight touch. In such case the lost member will grow again after a time.

177. **The snakes (Serpentes).**—The snakes are characterized by a cylindrical, generally greatly elongated body, in which the divisions into head, neck, trunk, and tail are not sharply defined. As we have seen, this is also true of certain lizards, but the naturalist finds no difficulty in detecting the differences between them. Another peculiarity of the snakes is in the great freedom of movement of the bones

not concerned with the protection of the brain. In the reptiles the lower jaw does not unite directly with the skull, as in the higher animals, but to an intermediate bone, the quadrate, which is attached to the skull. In the snakes these unions are made by means of elastic ligaments. The two halves of the lower jaw are also held

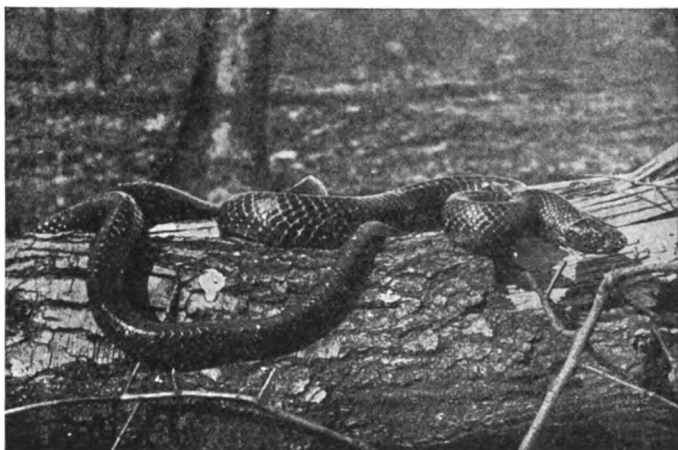


FIG. 112.—Blacksnake (*Bascanion constrictor*). Photograph by W. H. FISHER.

together by a similar band, so that the entire palate and lower jaw are loosely hung together. This enables the snake to distend its mouth and throat to an extraordinary degree, and to swallow frogs and toads but slightly smaller than itself. Where the prey is of relatively small size, the halves of the lower jaw alternate with each other in pulling backward, thus drawing the food down the throat. The food is never masticated. The teeth are usually small and recurved, and serve only to hold the food until it may be swallowed. The latter process is facilitated by the copious secretion of the salivary glands, which become very active at this time.

A further character of the snakes is the absence exter-

nally of any trace of limbs. However, in some of the pythons and boas hind limbs are present in the form of small groups of bones embedded beneath the skin and terminating in a claw. There thus appears to be no doubt that the ancestors of the modern snakes were four-footed, lizard-like creatures, which have assumed the present form in response to the necessity of adaptation to new conditions.

More than any other order of vertebrates do the snakes deserve the name of creeping things, and yet their method of locomotion enables them to crawl and swim with a rapidity equal to that of many of the more highly developed animals. This depends chiefly upon certain peculiarities of the skeleton, which consists merely of a skull, vertebral column, and ribs. The vertebræ, usually two or three hundred in number, are united together by ball-and-socket joints, and each attaches by similar joints a pair of slender ribs. These in turn are attached to the broad outer plates upon which the body rests, and the whole system is operated by a powerful set of muscles. Upon the contraction of the muscles the ventral plates are made to strike backward upon the ground or other rough surface, which drives the body forward. Also, the ribs may be made to move backward and forward, and the snake thus progresses like a centiped or "thousand-legs."

178. **The turtles (*Chelonia*).**—In many respects the turtles are the most highly modified of all the reptiles. The body (Fig. 113) is short and wide and enclosed in a shell or heavy armor, consisting of an upper portion, the carapace, and a flat ventral plate, the plastron. The shape of the carapace varies greatly from a low, flat shield to a highly vaulted dome, remaining cartilaginous throughout life, as in the soft-shelled turtles, or becoming bony and of great strength. The two portions of the shell form a box-like armor through whose openings may be extended the head, tail, and limbs. As a means of protection the turtle may retract these organs within the shell. The head is generally

thick-set and muscular, and provided with horny jaws entirely destitute of teeth, like those of the birds. The limbs also are usually short and thick and variously shaped, and adapted for aquatic or terrestrial locomotion. The number of vertebræ in the body and tail are relatively few, and the thick and heavy body is devoid of the elements of grace and agility of movement characteristic of the other reptiles. On the other hand, the former enjoy a freedom from the attacks of enemies not accorded to animals in general.

At first sight the appearance of a turtle does not indicate a close relationship to the other reptiles, but a more

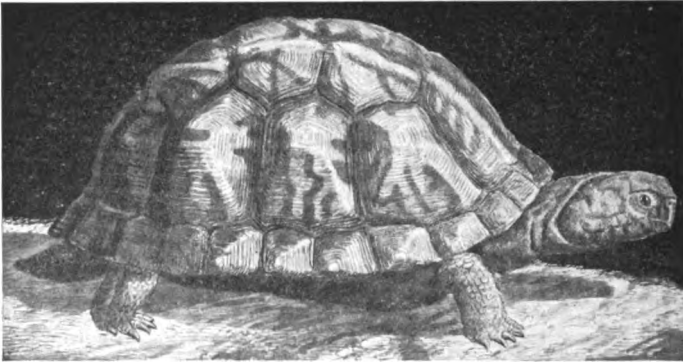


FIG. 113.—Box-turtle (*Terrapene carolina*).

careful examination, and especially of their development, discloses a remarkable resemblance. The head, tail, and limbs are essentially similar to those of the lizards, but in the trunk region peculiar modifications have taken place. The ribs at first separate, as in other animals, flatten greatly, and unite with a number of bones embedded in the skin, thus forming one great plate overlying the back of the animal. About the circumference of the shield other dermal or skin-bones are added, which increase the area of the carapace, and at the same time still others have

arisen and united on the ventral surface to form the plastron. In this process the shoulder- and hip-girdles which attach the limbs come to be withdrawn into the body, and we have the curious example of an animal enclosed within its back-bone and ribs. This is even more the case with the box-turtles (Fig. 113), common in the eastern United States, whose ventral plate is hinged so that after the limbs, head, and tail have been withdrawn it may be made to act like a lid to completely enclose the fleshy parts of the body.

Scales and horny plates are present, as in other reptiles, the former covering all parts of the body except the carapace and plastron, which support the plates. In nearly all species the latter are of considerable size, and in the tortoise-shell turtles are valuable articles of commerce. They also are sculptured in a fashion characteristic of each species, and may, like the colors of other animals, render them more like their surroundings, and consequently inconspicuous.

179. Crocodiles and alligators (Crocodylia).—The alligators (Fig. 114) and crocodiles are much more complex in structure than the lizards, though their general form is much the same. The body is covered with an armor of thick bony shields and horny scales. These, along the median line, are keeled, and extending along the length of the laterally compressed tail form an efficient swimming organ and rudder. The mouth is of large size, and is bounteously supplied with large conical teeth, which are set in sockets in the jaw, and not fused with it, as in many of the lizards. The nose and ears may be closed by valves to prevent the entrance of water, and a similar structure blocks its passage beyond the throat while the mouth is open. When large animals, such as hogs or calves, are captured as they come to drink, these devices enable the alligator or crocodile to sink with them to the bottom and hold them until drowned. The limbs, short and powerful, are efficient organs of locomotion.

tion on land, and together with the general shape of the body, are also well adapted for swimming.

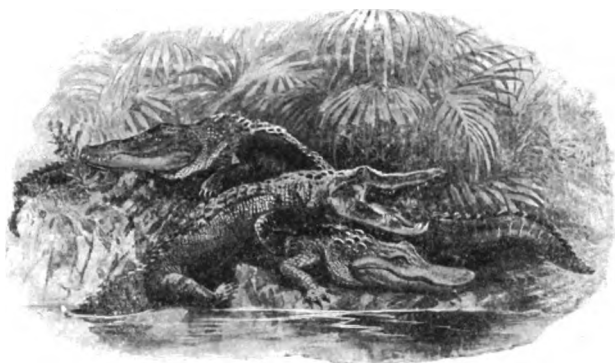


FIG. 114.—Alligator (*Alligator mississippiensis*).

180. Distribution of the lizards.—In a general way the number of reptiles is greatest where the temperature is highest. The tropics therefore abound in species, often of large size, and usually of bright coloration. As one travels northward the numbers rapidly diminish, their size is smaller, and the tints less pronounced. In all probability not less than four thousand known reptiles exist, whose haunts are of the most varied description.

In North America the lizards are almost exclusively confined to the southern portions, only a very few species extending up to the fortieth parallel. Among these the skinks (*Eumeces*) are most widely distributed. The blue-tailed skink is probably the most familiar, a small lizard eight or ten inches in length, dark green with yellowish streaks and a bright-blue tail. On sunny days it may sometimes be seen darting about on the bark of trees in search of insects, upon which it feeds.

One of the most familiar lizards in this country is the "glass-snake," found burrowing in the drier soil of the southern half of the United States east of the Mississippi.

Both pairs of limbs are absent, but by wriggling movements of the body this lizard is able to force its way through light soil with considerable rapidity. It is a matter of some difficulty to secure entire specimens, for with other than the gentlest handling the tail severs its connection with the body, as the vertebræ in this portion are extremely brittle. This peculiarity, together with its shape, has given it the popular name of glass-snake. Many species of lizards will thus detach the tail, a habit which is a means of protection, enabling the animal to scamper away into a place of safety while its enemy is concerning itself with the detached member. Later on a new tail develops, though usually of a less symmetrical form.

181. **Horned toads.**—The horned toads (*Phrynosoma*) are lizards peculiar to the hot, sandy deserts and plains of

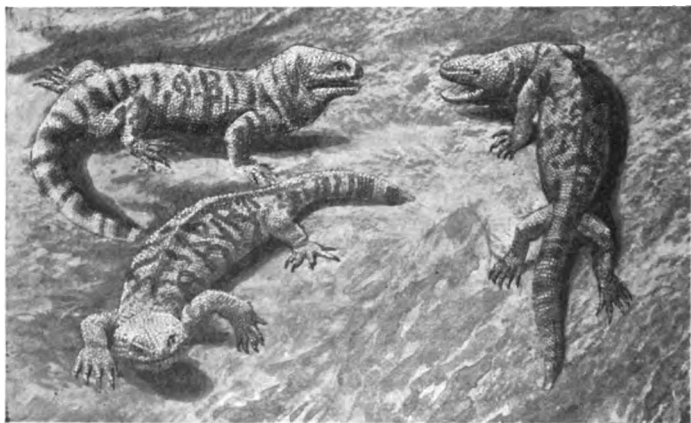


FIG. 115.—Gila monster (*Heloderma suspectum*). One-third natural size.

Mexico and the western United States. The body is comparatively broad and flat, almost toad-like, and is covered with scales and spines of brownish and dusky tint, so like dried sticks and cactus spines in form and color as to render them difficult of detection. In captivity they readily

adapt themselves to their new surroundings, become tame, and feast on flies, ants, and other insects, which they capture by the aid of their long tongue. The horned toads are perfectly harmless creatures, but when irritated sometimes perform the remarkable feat of spurting a stream of blood from the eye toward the intruding object for a distance of several inches. This has been regarded by some as a zoological fable; but there are many who have watched the horned toad in its natural state and in captivity, and they assure us that it is a fact.

In the hot deserts of Arizona and Sonora is another peculiar species of lizard known as the Gila monster (*Heterodermus*) (Fig. 115), having the distinction of being the only poisonous lizard known. Further protection is afforded by bony tubercles on the head and by scales over the remainder of the body, all of which are colored brown or various shades of yellow, giving the animal a peculiar streaked and blotched appearance.

182. Distribution of the snakes.—The snakes are much more common than the lizards. All over the United States one meets with them, especially the garter- or water-snakes. Of less wide distribution are the black-, grass-, and milk-snakes, and a number of less known species, all of which are perfectly harmless and often make interesting pets. Some of them when cornered show considerable temper, flatten the head and hiss violently, and imitate poisonous forms, but venomous snakes are comparatively few in number in northern and eastern United States. In the southern portions of the country they become more abundant. Along the streams and in the swamps the copperheads, and especially the water-moccasins, often lie in wait for frogs and fish. Both these species are especially dreaded, as they strike without giving any warning sound, but the name and bad reputation of the moccasin is often, especially in the South, transferred to perfectly harmless water-snakes. On higher ground are the rattlesnakes (*Crotalus*), once

abundant but now in many regions well-nigh exterminated. In these species the tail terminates in a series of horny

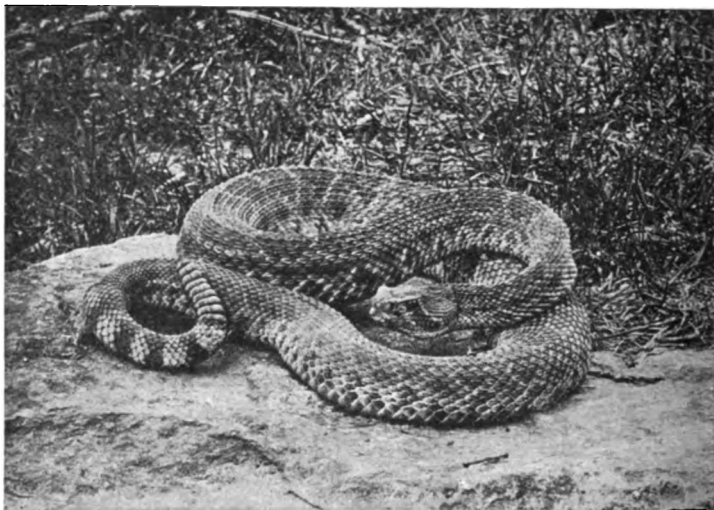


FIG. 116.—Diamond-rattlesnake (*Crotalus adamanfeus*). Photograph by W. H. FISHER.

rings that produce a buzzing sound like that of the locust when the tail is rapidly vibrated.

183. Distribution of the turtles.—The turtles are perhaps somewhat less dependent upon warmth than other reptiles, yet they too delight to bask in the sunshine, and soon grow sluggish in its absence. In all our fresh-water streams and ponds they are familiar objects, and several species extend up into Canada. Among the turtles the soft shell, the painted and the snapping turtles have the widest distribution, scarcely a good-sized stream or pond from the Gulf of Mexico to Canada, and even farther north, being without one or more representatives. All are carnivorous and voracious, and the snapping turtles are especially ferocious, and “for their size are the strongest of reptiles.” In the woods and meadows the wood-tortoise and box-turtles are occa-

sionally met with, and at sea several turtles exist, some of them of great size. Among these is the leather-turtle, found in the warmer waters of the Atlantic, lazily floating at the surface or actively engaged in capturing food. They attain a length of from six to eight feet, and a weight of over a thousand pounds, and are sometimes captured for food when they come ashore to bury their eggs in the sand. By this same method the loggerheads, the hawksbills, and the common green turtles are also captured in considerable numbers. These are of smaller size, and the second named is of considerable value, as the horny plates cover-

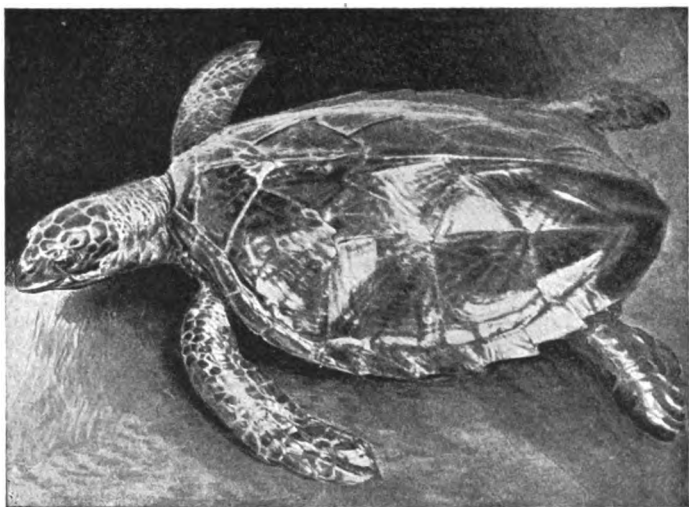


FIG. 117.—Hawksbill turtle (*Eretmochelys imbricata*).

ing the shell furnish the tortoise-shell of commerce. These plates are removed after the animal is killed, by soaking in warm water or by the application of heat.

184. Food and digestive system.—Some reptiles, among which are a number of species of lizards and the box- and green turtles, are vegetarians, but the great majority are

carnivorous, and usually very voracious. The lizards especially devour large quantities of insects and snails, together with small fishes and frogs. The latter figure largely in the turtle's bill of fare, and in that of the snakes, which also capture birds and mammals. On the other hand, many of the reptiles prey upon one another; and they are the favorite food of hawks and owls and numerous water-birds, of skunks and weasels and many other animals, which look for them continually. Many of the turtles, owing to their protective armor, and the snakes because of their poisonous bite or great size and strength, are more or less exempt, but this is not true of their eggs and young. The smaller species depend upon keenness of sense, agility, and inconspicuous tints. These latter may undergo changes according to the character of the surroundings, but usually only to a slight extent. The chameleons of the tropics and a similarly colored green lizard on the pine-trees in the Southern States are able to change with great rapidity from green, through various shades, to brown.

185. **Respiration and circulation.**—While still in the egg the young lizard develops rudimentary gills, and thus bears

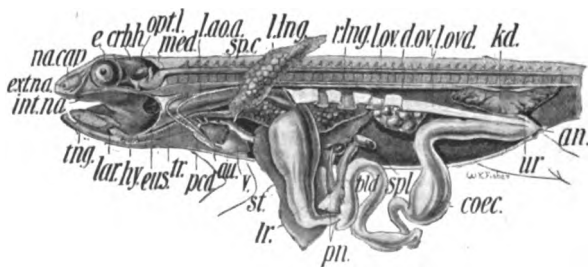


FIG. 118.—Dissection of lizard (*Sceloporus*). *an.*, anal opening; *au.*, auricle; *crb. h.*, brain; *coec.*, intestine; *kd.*, kidney; *l. lng.*, left lung; *tr.*, liver; *pn.*, pancreas; *sp. c.*, spinal cord; *spl.*, spleen; *st.*, stomach; *v.*, ventricle of heart.

evidence to the fact that its distant ancestors were aquatic; but before hatching they disappear, and lungs arise, which

remain functional throughout life. Corresponding to the shape of the body, these are usually much elongated and ordinarily paired (Fig. 118, *lung.*). The snakes are peculiar in having the left lung rudimentary or even lacking completely, while the right one becomes greatly elongated and extends far back into the body. In nearly all the reptiles the amount of oxygen brought into the lungs is relatively large and the activity of the animal is proportionately great. The circulation of reptiles shows an advance beyond that of the Amphibia. As in the latter, there are two distinct auricles; but the chief difference arises from the fact that the ventricle is more or less divided by a partition which to a considerable degree prevents the blood returning from the lungs from mixing with the impure blood as it returns from its journey over the body. In the crocodiles and alligators the partition is complete, and the circulation thus approaches close to that of the higher animals.

186. **Hibernation.**—Attention has already been called to the fact that reptiles are very susceptible to cold, rapidly growing less active as the temperature lowers. When winter comes on they seek protected spots, and either alone or grouped together hibernate. The various activities of the body during this period are at very low ebb. The blood barely circulates, breathing is imperceptible, and stiff and insensible to the world about them they remain until the warmth again stirs them to their former activity. Some of our common turtles must also pass a somewhat similar sleep while embedded far down in the mud during the disappearance of the ponds in summer. At such times no food is taken, but owing to their loss in weight it is probable that a slow consumption of the body supplies the small amount of necessary energy.

187. **Nervous system and sense-organs.**—At first sight one is struck with the small size of the brain of fishes, Amphibia, and reptiles. Their intelligence likewise is at low

ebb. Almost all the movements and operations of the body appear to be carried on by the animal with little apparent thought. Their acts, like most of the animals below them, are said to be instinctive; yet they are sufficiently well done to enable the animal to procure its food, avoid its enemies, and lead a successful life. As is true of other animals, the ability of the reptile to cope with its surroundings depends to a great extent upon the keenness of one or all of its organs of special sense. In the reptiles the sense of sight is perhaps sharpest, but there is considerable variation in this respect. Movable eyelids are present in most lizards, together with a third, known as the nictitating membrane, a thin, transparent fold located at the inner angle of the eye, over which it is drawn with great rapidity. Snakes have no movable eyelids, hence the eye has a peculiar stare. Furthermore, their sense of sight, except in a few tree-dwelling species, appears to be defective, the majority depending largely upon the sense of touch.

In all the vertebrates a very peculiar organ known as the pineal gland or eye is situated on the roof of the brain. In several lizards its position is indicated by a transparent area in one of the plates of the head, and by an opening in the bones of the roof of the skull. In young reptiles, and especially in one of the New Zealand lizards (*Hatteria*, Fig. 119), its resemblance to an eye is decidedly striking. Lens, retina, pigment, cornea, are all present much as they are in some of the snails, but they finally degenerate more or less as the animal reaches maturity. It is a general belief that it represents the remnant of an organ of sight, a third eye, which looked out through the roof of the skull in some of the ancient vertebrates.

With the possible exception of the few species of reptiles which produce sounds, probably to attract their mate, the sense of hearing is not particularly well developed. The senses of smell and taste are also comparatively feeble. The latter sense is located in the tongue, which is also popularly

supposed to serve for the purpose of defense, and that it is in some way related to the poison-glands. This, however, is an error. The tongue is used primarily as an organ of

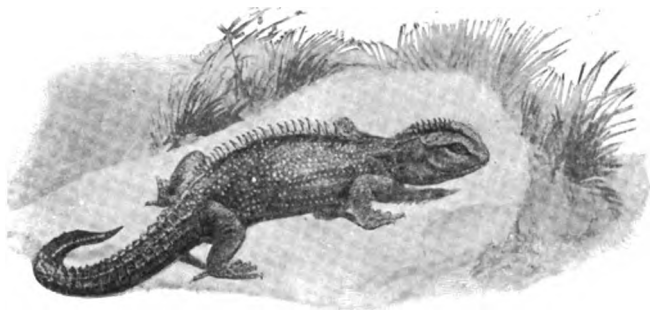


FIG. 119.—Tuatara (*Sphenodon punctatus*).

touch, and in snakes especially it is almost continually darted in and out to determine the character of the animal's surroundings.

188. **Egg-laying.**—The eggs of the reptiles are relatively large and enclosed in a shell like a bird's egg, the shell, however, being leathery rather than made of lime. These are deposited in some warm situation, and generally left to themselves to hatch. Under stones, logs, and leaves, or buried lightly in the soil, are the positions most frequently chosen by the lizards and snakes. The turtles almost invariably select the warm sand at the edge of the water, and after scooping a hole lay numerous spherical eggs, usually at night. The alligators lay upward of a hundred eggs about the size of those of a goose, and guard them jealously until and even after they hatch. On the other hand, the young of many lizards and snakes are born alive, the eggs being hatched within the body.

Many reptiles are surprisingly slow in attaining maturity, and live to an age attained by few other animals. It is a well-known fact that turtles live fully a hundred years, and

probably the same is true of the crocodiles and alligators and some of the larger snakes. Their enemies are few, and death usually results when the natural course is run.

Throughout life all reptiles periodically shed their skin, as birds do their feathers and mammals their fur. In the snakes and some of the lizards the skin at the lips loosens, and the animal gradually slips out of its old slough, bright and glossy in the new one which previously developed. In the others the old skin hangs on in tatters, gradually coming away as they scamper through the grass.

CHAPTER XVII

THE BIRDS

189. Characteristics.—Birds form one of the most sharply defined classes in the animal kingdom, and the variations among the different species are relatively small. "The ostrich or emu and the raven, for example, which may be said to stand at opposite ends of the series, present no such anatomical differences as may be found between a common lizard and a chameleon, or between a turtle and a tortoise," and these we know to be relatively slight.

In many respects the birds resemble the reptiles, and long ago in the world's history the relationship was much closer than now, as we know from certain fossil remains in this country and in Europe. One of the earliest of these fossil birds, the *Archæopteryx*, is a most remarkable combination of bird and lizard. Unlike any modern bird, the jaws were provided with many conical reptile-like teeth. The wings were rather small, and the fingers, tipped with claws, were distinct, not grown together, as in modern birds. The tail was as long as the body, and many-jointed, like a lizard's, each vertebra carrying two long feathers. The bird was about the size of a crow, and it probably could not fly far. Other ancient types have been discovered—principally sea-birds—many of which existed when the Pacific extended over the region now occupied by the Rocky Mountains. These were all of the same generalized type, intermediate between reptile and bird. This fact leads us to the belief that birds descended from reptilian

ancestors, and in becoming more perfectly adapted for an aerial life have developed into our modern forms.

In the modern birds the most important peculiarities, those which separate them from all other animals, are correlated with the power of flight. The body is spindle-shaped, for readily cleaving the air. The fore limbs serve as wings. The hind limbs, supporting the weight of the body from the ground, are usually well developed. A series of air-chambers usually exists in powerful fliers. This serves a purpose analogous to that of the air-bladder of a fish, giving buoyancy. But the most characteristic mark of a bird, as above stated, is its feathers, universally present and never found outside the class. Like the scales of lizards, and probably derived from similar structures, they are of different forms, and serve a variety of purposes. The larger ones, with powerful shafts, and forming the tail, act as a rudder. Those of the wings give great expanse with but little increase in weight, and are so constructed that upon the down-stroke they offer great resistance to the air, and push the bird forward, while in the reverse direction the air slips through them readily. In flight these movements of the wing may be too rapid for us to follow, as in the humming-birds, though they are usually much slower, two to five hundred a minute in many powerful fliers, such as the ducks, and frequently long-continued enough to carry them many hundreds of miles at a single flight. The remaining feathers are soft and downy, giving roundness to the body and enabling it to cleave the air with greater ease, and, being poor conductors of heat, they aid in keeping the body at the high temperature characteristic of birds. In most birds the body is not uniformly clothed in feathers. Naked spaces, usually hidden, intervene between the feather tracts, and on the feet and toes scales exist.

190. **Molting.**—As we all know, the growth of feathers, unlike that of hair and nails, is limited, and after they have become faded and worn out they are shed, and new ones

arise to take their place. This process of molting is usually accomplished gradually, without diminishing the powers of flight; but in the ducks and some other birds all the wing- and tail-feathers drop out simultaneously, leaving the bird to escape its enemies by swimming and diving. The molting-process usually takes place in the fall, after the nesting and care for the young is over, and often when the need for a heavy winter coat commences to be felt. Many birds also don what are called courting colors, ruffs, crests, and highly colored patches, in the spring, previous to the mating season, doubtless for the purpose of attracting or impressing their mates. In other cases the change appears to be related to the bird's surroundings. A most beautiful example of this is the ptarmigans—grouse-like birds living far to the north. During winter they are perfectly white and are almost invisible against the snow; but in the spring, as the snow disappears, the white feathers gradually fall out and new ones arise. The latter so harmonize "with the lichen-colored stones among which it delights to sit, that a person may walk through a flock of them without seeing a single bird."

There are also numerous birds, chiefly those that go in flocks, which possess what are known as color-calls or recognition-marks. These may consist of various conspicuous spots or blotches on different parts of the head or trunk, such as we see in the yellowhammer or meadow-lark; or one or more feathers of the wings or tail may be strikingly colored, as in many sparrows and warblers. During the time the bird remains at rest these usually are concealed under neighboring feathers, but during flight they are strikingly displayed. It may possibly be true, as many have urged, that these color-signals are for the purpose of enabling various members of the flock to readily follow their leader; but this and many other interesting questions regarding the color of birds and other animals have not yet received final answers.

In very many animals, fishes as well as birds, the tints on the under side of the body are usually relatively light colored, shading gradually into a darker tint above. This is in all probability a protective device, as was recently shown by Mr. A. H. Thayer, an American artist. His experiments show that the light from above renders the back less dark, and that the shadow beneath is neutralized by the light color. The bird thus appears uniformly lighted, and this effect, together with streaks and blotches, renders them invisible at surprisingly short distances.

191. **Skeleton.**—Turning now to the internal organization of birds, we find many points in common with other vertebrates, especially the reptiles, but many interesting modifications are also present that adapt them for flying and for collecting their food. According to the nature of the food, the beak may have a great variety of forms. The skull may be thick and heavy, or thin and fragile, but these are matters of proportion of the various parts possessed by all birds. The neck also is of differing length; but it is in the trunk region that the greatest changes have arisen, as we may see in any of our ordinary birds. For example, the vertebræ of this part of the body are more or less fused together into rigid framework, to which are attached the ribs that in turn unite with the breast-bone. In the fliers the latter bears a vertical plate or keel, to which the great muscles that move the wings are attached. The tail consists, like that of the old-fashioned birds, of several vertebræ, but these are of small size and fused together into a little knob that supports the tail-feathers. The fore limbs are used for flight, but there are the same bones that exist in the fore limbs of other vertebrates—one for the upper arm, two for the lower, a thumb carrying a few feathers, and known as the bastard wing, and indications of several bones that form the hand. In the hind limb the resemblance is equally apparent, though its different parts are of relatively large size to support the body. It is interest-

life. The life of birds is at high pressure, hence their need of much oxygen. They habitually breathe deeper breaths than other animals. The air passing into the body traverses the entire extent of the lung on its way back to the air-sacs, with the result that large quantities of oxygen are taken into the body. This is distributed by a circulatory system of a more highly developed type than in any of the preceding groups of animals. The ventricles of the heart no longer communicate with each other, and the pure and impure blood never mingle. Furthermore, the beating of the heart is comparatively rapid, rushing the oxygen as fast as it enters the blood to all portions of the body. The result is that everywhere heat is being generated, so necessary to life and activity.

In the lower animals no special means are employed to husband the energy thus produced, but in the birds the body is jacketed in a non-conducting coat of feathers which prevents its dissipation. For this and other reasons the birds, summer and winter, maintain an even and relatively high temperature (102° – 110°). Like the mammals, birds are warm-blooded animals, full of energy, restlessly active to an extent realized in few of the cold-blooded animals.

193. Digestive system.—This life, at high pressure, demands a relatively large amount of food to make good the losses due to oxidation. The appetites of some growing birds is only satiated after a daily meal equal to from one to three times their own weight, and after reaching adult size the amount of daily food required is probably not less than one-sixth their weight. The nature of the food is exceedingly varied, and the digestive tract and certain accessory structures are obviously modified in accordance with it. The beak, always devoid of teeth in the living form, varies extremely according to the work it must perform. The same is true of the tongue, and many correlated modifications exist in the digestive apparatus. In the birds of prey and the larger seed-eating species, such as the

pigeons and the domestic fowls, the esophagus dilates into a crop, in which the food is stored and softened before being acted upon by the gizzard. The latter is the stomach, provided with muscular walls, especially powerful in the seed-eaters, and with an internal corrugated and horny lining which, in the absence of teeth, serves to crush the food. In some species, such as the domestic fowls and the pigeons, this process is aided by the grinding action of pebbles swallowed along with the food. The remaining portions, with pancreas and liver, vary chiefly in length, and are sufficiently shown in Fig. 120 to require no further description.

194. Nesting-habits.—A few birds, such as the ostriches and terns, merely scoop a hollow in the earth, and make no further pretense of constructing a nest. On the other hand, some birds, such as the humming-birds and pewees, build wonderful creations of moss, lichens, and spider-webs, lining it with down, and concealing it so skilfully that they are not often found. Every bird has its own particular ideas as to the fitness of its own nest, and the results are remarkably different, and form an interesting feature in studying the habits of birds. Usually the female takes upon herself the choice of the nest and its construction; but these duties are in some species shared by the male. After the eggs are laid, the male may also aid in their incubation, or may carry food to the female. In other species—for example, the pigeons and many sea-birds—the parents take turns in sitting upon the eggs and in the subsequent care of the young. Finally, there are certain birds, such as the cuckoo and cowbirds, which take advantage of the industry of other species and deposit an egg or two in the nests of the latter. All the work of incubation and care of the young is assumed by the foster-parents, which sometimes neglect their own offspring in their desperate attempts to satisfy the appetites of the rapidly growing and unwelcome guests.

The eggs of birds are relatively large, and are often delicately colored. In some species the blotches and streaks of different shades are probably protective, as in the plovers and sandpipers, whose eggs blend perfectly with their surroundings, but many other cases exist not subject to such an explanation.

The young require a high degree of heat for their development, and this is usually supplied by the parent. In a very general way the length of sitting, or incubation, is proportional to the size of the egg, being from eleven to fourteen days in the smaller species, to seven or eight weeks in the ostriches. Before hatching, a sharp spine develops on the beak, and with this the young bird breaks its way through the shell. Among the quails, pheasants, plovers, and many other species, the young are born with a covering of feathers, wide-open eyes, and the ability to follow their parents or to make their own way in the world. Such nestlings are said to be *precocial*, in distinction to the *altricial* young of the more highly specialized species, such as the sparrows, woodpeckers, doves, birds of prey, and their allies, which are born helpless and depend for a considerable time on the parents for support.

Some of the owls, crows, woodpeckers, sparrows, quails, etc., remain in the same localities where they are bred. They are resident birds. Most kinds of birds, at the approach of winter, migrate toward the southern warmer climes, some species traveling in great flocks, by day or night, and often at immense heights. In some cases this movement appears to be directly related to the food-supply; but there are many apparent exceptions to such a theory, and it is possible that many birds migrate for other reasons. Certain species migrate thousands of miles, along fairly definite routes, the young, sometimes at least, guided by the parents, which in turn appear to remember certain landmarks observed the year before. Sea-birds, in their journeys northward or southward, keep alongshore, occa-

sionally veering in to get their bearings or to rest, especially in the presence of fogs.

195. Classification.—Most zoologists make two primary divisions of the living types of birds—those like the ostrich with flat breast-bones, and the other the ordinary birds, in which the breast-bone has a strong keel for the attachment of the powerful muscles used in flight. This distinction is not of high importance, but we may use it as a convenience in the description of a few typical forms belonging to several orders into which these two divisions are subdivided.

196. The ostriches, etc. (Ratitæ).—From specimens introduced or from pictures we are doubtless familiar with the ostriches and with some of their relatives. The African ostrich (*Struthio camelus*, Fig. 121) is the largest of living birds, attaining a height of over seven feet, and is further characterized by a naked head and neck, two toes, and fluffy, plume-like feathers over parts of the body. They are natives of the plains and deserts of Africa, where they travel in companies, several hens accompanying the male. When alarmed, they usually escape by running with a swiftness greater than that of the horse, but if cornered they defend themselves with great vigor by means of their powerful legs and beaks. Their food consists of insects, leaves, and grass, to which is added sand and stones for grinding the food, as in the domestic fowl. The American ostriches or rheas, are smaller ostrich-like birds, living on the plains of South America. Their habits are essentially the same as those of the African species.

197. The loons, grebes, and auks (Pygopodes).—The birds in this and some of the following orders are aquatic in their habits. All have broad, boat-like bodies, which, with the thick covering of oily feathers, enables them to float without effort. The legs are usually placed far back on the body—a most favorable place for swimming, but it renders such birds extremely awkward on land. The grebes are preeminently water-birds. The pied-billed grebe or dab-

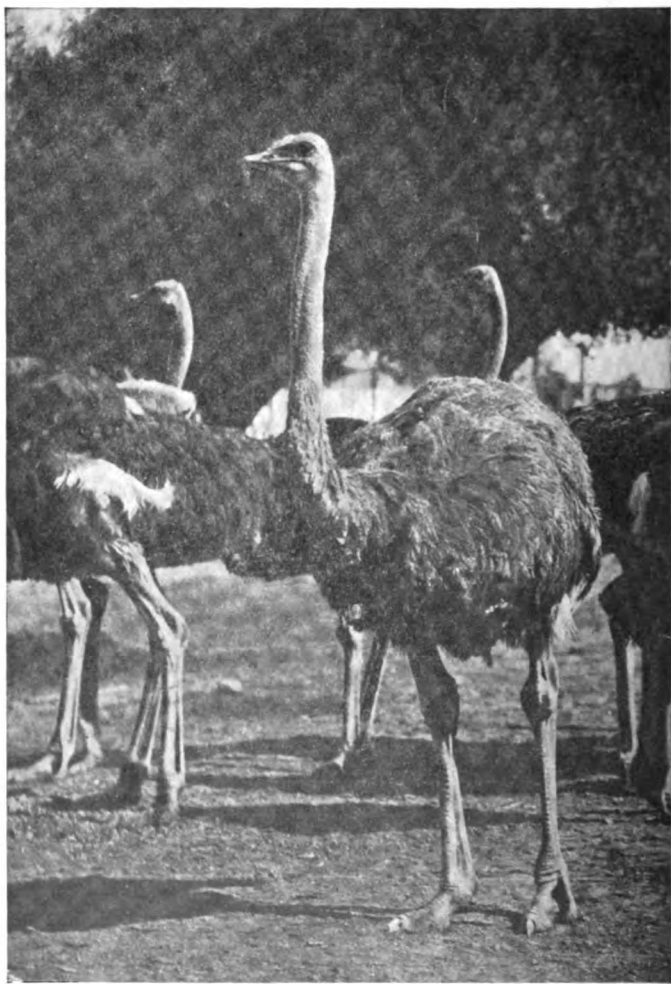


FIG. 121.—African or two-toed ostrich (*Struthio camelus*). Photograph by WILLIAM GRAHAM.

chick (*Podilymbus podiceps*), for example, found abundantly on the larger lakes and streams throughout the United States, captures its food, sleeps, and breeds without leaving the water. The loons living in the same situations as the dabchick are also remarkable swimmers and divers. Of the three species found in this country, the common loon or diver (*Gavia imber*) attains a length of three feet, and is otherwise distinguished by its black plumage, mottled and barred with white, which is also the color of the under parts. The auks, murres (see frontispiece), and puffins are marine, and, like their inland relatives, are expert swimmers and divers, strong fliers, and spend much of their time on the open sea. During the breeding-season they assemble in vast numbers on rugged cliffs along the shore, and lay their eggs on the bare rock or in rudely constructed nests.

198. The gulls, terns, petrels, and albatrosses (Longipennes).—The birds belonging to this group are among the most abundant along the seacoast, and several species make their way inland, where they often breed. All are characterized by long, pointed wings and pigeon or swallow-like bodies, which are carried horizontally as the bird waddles along when ashore. Many are excellent swimmers and powerful fliers, especially the petrels and albatrosses, which sometimes travel hundreds of miles at a single flight.

The gulls are abundantly represented along our coasts, where they frequently associate in companies, usually resting lightly on the surface of the water, or wheeling lazily through the air on the lookout for food. The terns are of lighter build than the gulls and are more coastwise in their habits, and are further distinguished by plunging like a kingfisher for the fishes on which they live. Both the gulls and terns breed in colonies, every available spot over acres of territory being occupied by their nests, which are usually built of grass and weeds placed on the ground.

The petrels and albatrosses are at home on the high

seas, rarely coming ashore except at the breeding-season. Some species of the former are abundant off our shores, especially the stormy petrel (*Procellaria pelagica*) or Mother Carey's chickens (*Oceanites oceanicus*), which are often seen winging their tireless flight in the wake of ocean vessels. Among the dozen or so albatrosses few reach our shores. The wandering albatross (*Diomedea exulans*), celebrated in story and as the largest sea-bird (fourteen feet between the tips of its outstretched wings), is an inhabitant of the southern hemisphere, and only rarely extends its journeys to more northern regions.

199. **Cormorants and pelicans (Steganopodes).**—The cormorants and pelicans are comparatively large water-birds



FIG. 122.—White pelicans (*P. erythrorhynchos*) and whooping-crane (*Grus americana*). Photograph by W. K. FISHER.

usually abundant along the seashore and in many sections of the United States. The cormorants or shags are glossy

black in color, with hooked bills, long necks, and short wings, which give them a duck-like flight. The much larger pelicans (Fig. 122) are at once distinguished by long bills, from which is suspended a capacious membranous sac. All these birds are sociable in their habits, breeding, roosting, and fishing in great flocks. Their food consists of fishes, which the shags pursue under water and capture in their hooked beaks; while the pelicans, diving from a considerable height or swimming rapidly on the surface, use their pouches as dip-nets. The nests, usually built of seaweed or of sticks, are placed on rocky cliffs or on the ground in less elevated places.

200. **Ducks, geese, and swans** (*Lamellirostres*).—The birds of this order, with their broad, flat, serrated beaks, short legs, and webbed feet, are well known, for in a wild or domesticated state they extend all over the earth. All are excellent swimmers, many dive remarkably well, and are strong on the wing. While a considerable number breed within the United States, their nesting-grounds are generally farther north, and in the early spring it is not unusual to see them migrating in flocks from their warmer winter homes. Among the ducks, the mergansers, mallards (from which our domestic species have been derived), the teals, and the beautiful wood-duck remain with us the year round, dwelling on quiet streams and shallow ponds, living on fish, Crustacea, and seeds. In the more open waters of the larger lakes and along the seacoast we find the canvasback, the scaup-ducks, and the eiders (Fig. 123) which supply the famous down of commerce. Of the few species of geese which inhabit the United States, the Canada goose (*Branta canadensis*) is perhaps the most familiar. During their migrations to the nesting sites they fly in V-shaped flocks, their “honks” announcing the opening of spring. The brant (*B. bernicla*) is also common in the eastern part of the country, where it, like its relations, lives on vegetable substances entirely. The swans are familiar in their semi-

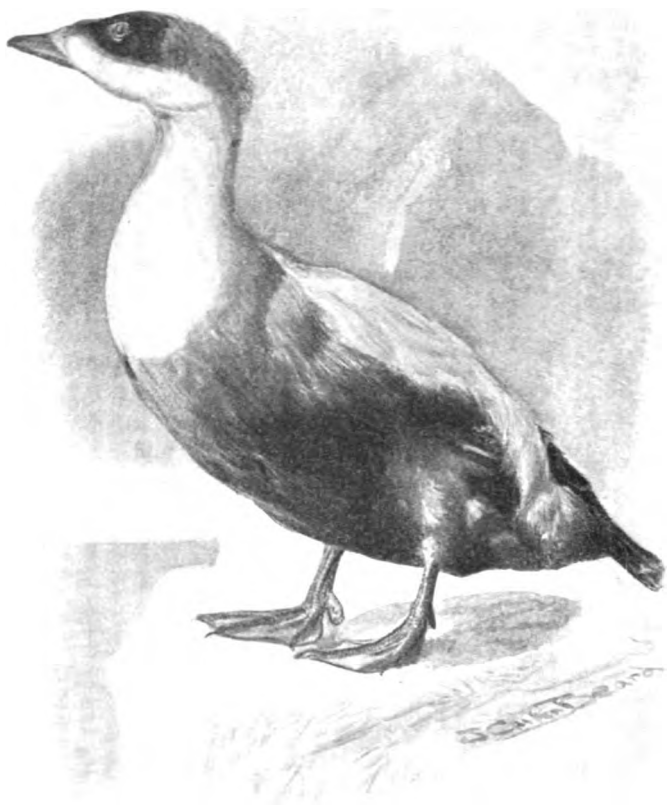


FIG. 123.—American cider-duck (*Somateria dresseri*).

domesticated state, but the two beautiful wild swans found in this country are rarely seen.

201. **The herons and bitterns (Herodines).**—The herons and bitterns are also aquatic in their habits, but, unlike the swimming-birds, they seek their food by wading. Adapting them for such an existence, the legs and neck are usually very long, and the bill, longer than the head, is sharp and slender. Among the relatively few species in the United States, the great blue heron (*Ardea herodias*) is widely distributed, and may often be seen standing motionless in some shallow stream on the lookout for fish, or it may wander away into the meadows and uplands to vary its diet with frogs and small mammals. Even more familiar is the little green heron or poke (*Ardea virescens*), which also is seen widely over the country. The night-herons, as their name indicates, stalk their prey by night, and during the day roost in companies—a characteristic common to most herons. The bitterns or stake-drivers are at home in reedy swamps, where they live singly or in pairs, and throughout the night, during times of migration, utter a booming noise resembling the driving of a stake into boggy ground. As a rule, the herons breed as they roost—in companies—building bulky platforms, usually in trees. The bitterns, on the other hand, secrete their nests on the ground in the rushes of their marshy home.

202. **Cranes, rails, and coots (Paludicolæ).**—In their external form the cranes and rails resemble the herons, but in their internal organization they differ considerably. They likewise inhabit marshy lands, but usually avoid wading, picking up the frogs, fish, and insects or plants along the shore or from the surface of the water. The cranes are comparatively rare in this country, yet one may occasionally meet with the whooping-cranes (*Grus americana*) and sand-hill cranes (*Grus mexicana*), especially in the South and West. They are said to mate for life, and annually repair to the same breeding-grounds, where they build their

nests of grass and weeds on the ground in marshy places. The rails are more abundant, though rarely seen on account of their habit of skulking through the swamp grasses. Only rarely do they take to the wing, and then fly but a short distance, with their legs dangling awkwardly. Closely related to them are the coots or mud-hens (*Fulica americana*), which may be distinguished, however, by their slaty color, white bills, and lobed webs on the toes, and consequent ability to swim. All over the United States they may be seen resting on the shores of lakes or quiet streams, or swimming on the surface gathering food. The nest consists of a mass of floating reeds, which the young abandon almost as soon as hatched.

203. **The snipes, sandpipers, and plovers (Limicolæ).**—The snipes, sandpipers, and plovers are usually small birds, widely scattered throughout the country wherever there are sandy shores and marshes. In most species the legs are long, and in connection with the slender, sensitive bill fit the bird for picking up small animals in shallow water or probing for them deep in the mud. During the greater part of the year they travel in flocks, but at the nesting-season disperse in pairs and build their nests in shallow depressions in the earth. The eggs are usually streaked and spotted, in harmony with their surroundings, as are the young, which leave the nest almost as soon as hatched.

Fully fifty species of these shore-birds live within the confines of the United States. Among these the woodcock (*Philohela minor*) and snipe (*Gallinago delicata*) are abundant in many places inland, where they probe the moist soil for food, and in turn are eagerly sought by the sportsman. Even more familiar are the sandpipers and plovers, which are especially common along the seacoast, and are also abundantly represented by several species far inshore. Among the latter are the well-known spotted sandpiper or "tip-up" (*Actitis macularia*) and the killdeer plover (*Ægi-*

alitis vocifera), which inhabit the shores of lakes and streams throughout the country.

204. **Quail, pheasants, grouse, and turkeys** (*Gallinæ*).—The quail, grouse, and our domestic fowls are all essentially



FIG. 124.—California quail (*Lophortyx californicus*). Two-thirds natural size.

ground-birds, and their structure well adapts them to such a life. The body is thick-set, the head small, and the beak heavy for picking open and crushing the seeds and berries

upon which they live. The legs and feet are stout, and fitted for scratching or for running through grass and underbrush. Protective colors also prevent detection, but if close pressed they rise into the air with a rapid whirring of their stubby wings, and after a short flight settle to the ground again. During the breeding-season the male usually mates with a number of hens, which build rough nests in hollows in the ground, where they lay numerous eggs. The young are precocial.

The quail or bob-white (*Colinus virginianus*) and the ruffed grouse (*Bonasa umbellus*) occur throughout the Eastern States. Over the same area the wild turkey (*Meleagris gallopavo*) once extended, but is now almost extinct. The prairies of the middle West support the prairie-hen (*Tympanuchus americanus*), and the valleys and mountains of the far West are the home of several species of quails, some of which are beautifully crested.

205. **Pigeons and doves (Columbæ).**—The pigeons and doves belong to a small yet well-defined order, with upward of a dozen representatives in the United States. They are of medium size, with small head, short neck and legs, and among other distinguishing characters frequently possess a swollen, fleshy pad in which the nostrils are placed. In former years the passenger-pigeon (*Ectopistes migratorius*), inhabiting eastern North America, was probably the most common species in this country. Their flocks contained thousands, at times millions, of individuals, which often traveled hundreds of miles a day in search of food, to return at night to definite roosts—a trait which enabled the hunter to practically exterminate them. At present the mourning- or turtle-dove (*Zenaidura macroura*) is the most familiar and wide-spread of the wild forms. The domestic pigeons are all descendants of the common rock-dove (*Columba livia*) of Europe, the numerous varieties such as the tumblers, fantails, pouters, etc., being the product of man's careful selection. In the construction of the nest, usually

a rude platform of twigs, and in the care of the young both parents have a share. The young at hatching are blind, naked, and perfectly helpless, and are fed masticated food from the crops of the parents until able to subsist on fruits and seeds.

206. **Eagles, hawks, owls, etc. (Raptores).**—The birds of prey, all of which belong to this order, are carnivorous, often of large size and great strength, and are widely distributed throughout this country. The vultures live on carrion, some of the small hawks and owls on insects, while the majority capture small birds and mammals by the aid of powerful talons. In every case the beak is hooked, and the perfection of the organs of sight and hearing is unequaled by any other animal, man included. They live in pairs, and in many species mate for life. As a rule, the female incubates the eggs, and the male assists in collecting food.

Among the vultures, the turkey-buzzard (*Cathartes aura*) is most abundant throughout the United States, especially in the warmer portions, where it plays an important part as a scavenger. Of the several species of hawks, the white-rumped marsh-hawk (*Circus hudsonius*), the red-tailed hawk (*Buteo borealis*), the red-shouldered hawk (*Buteo lineatus*), and above all the bold though diminutive sparrow-hawk (*Falco sparverius*) are the most abundant and familiar. In the more unsettled regions live the golden eagle (*Aquila chrysaetus*) and bald eagle (*Haliaetus leucocephalus*). The owls are nocturnal, and not so often seen as the other birds of prey, yet the handsome and fierce barn or monkey-faced owl (*Strix pratincta*), and the larger species, such as the great gray owl (*Scotiaptex cinerea*), and the beautiful snowy owl (*Nyctea nyctea*), are more or less common, and occasionally seen. Much more abundant is the little screech-owl (*Megascops asio*), and in the Western States the burrowing-owl (*Speotyto cunicularia*), which lives in the burrows of the ground-squirrels and prairie-

dogs. Fiercest and strongest of the tribe is the great horned owl (*Bubo virginianus*).



FIG. 125.—Golden eagle (*Aquila chrysaetos*).

207. Cuckoos and kingfishers (*Coccyges*).—Omitting the order of parrots (*Psittaci*), whose sole representative in this country is the almost exterminated Carolina parrakeet

(*Conurus carolinensis*), we next arrive at the cuckoos and kingfishers, which differ widely in their habits. The black- or yellow-billed cuckoos or rain-crows are shy, retiring birds, with drab plumage, and though seldom seen are often fairly abundant, and are of much service in destroying insects. Unlike their shiftless European relatives, which lay their eggs in the nests of others birds, they build their own airy homes in some bush or hedgerow, and raise their brood with tender care. The belted kingfisher (*Ceryle alcyon*) is also of a retiring disposition, and spends much of its time on some branch overlooking the water, occasionally varying the monotony by dashing after a fish, or flying with rattling cry to another locality. Their nests are built in holes in banks, and six or eight young are annually reared.

208. **The woodpeckers (Pici).**—The woodpeckers are widely distributed throughout the world, and are preeminently fitted for an arboreal life. The beak is stout for chiseling open the burrows of wood-boring insects, which are extracted by the long and greatly protrusible tongue. The feet, with two toes directed forward and two backward, are adapted for clinging, and the stiff feathers of the tail serve to support the bird when resting. Almost all are brightly colored, with red spots on the head, at least in the males, which may further attract their mates by beating a lively tattoo with their beaks on some dry limb. The glossy white eggs are laid in holes in trees, and both parents are said to share the duties of incubation and feeding the young. Among the more abundant and well-known species is the yellowhammer or flicker (*Colaptes auratus*), which extends throughout the United States. Somewhat less widely distributed is the red-headed woodpecker (*Melanerpes erythrocephalus*), and the small black-and-white downy woodpecker (*Dryobates pubescens*). This is often called sapsucker, but incorrectly so, as, like all but one of our other woodpeckers it feeds on insects. The yellow-bellied wood-

pecker (*Sphyrapicus varius*) is a real sapsucker, living on the juices of trees. A close relative of the red-headed woodpecker, the California woodpecker (*Melanerpes formicivorus*), is renowned for its habit of boring holes in bark and inserting the acorns of the live oak. Subsequently the bird returns, and breaking open the acorns, devours the grubs which have infested them, and apparently eats the acorns also.

209. **Swifts, humming-birds, etc. (Macrochires).**—The birds of this order are rapid, skilful fliers, and their wings are very long and pointed. The feet, on the other hand, are



FIG. 126.—Night-hawk (*Chordeiles virginianus*) on nest. Photograph by H. K. JON.

small, relatively feeble, and adapted for perching or clinging. Accordingly, the insects upon which they feed are taken during flight by means of their open beaks. The night-hawk (*Chordeiles virginianus*), roosting lengthwise on a branch by day, at nightfall takes to the wing, and high in the air pursues its food after the fashion of a swallow. In the same haunts throughout the United States the whip-

poorwill (*Antrostomus vociferus*) occurs, sleeping by day, but active at night. Neither of these birds constructs nests, but lays its streaked and mottled eggs directly on the ground. The chimney-swifts (*Chætura pelagica*), swallow-like in general form and habits, but very unlike the swallows



FIG. 127.—Anna hummers (one day old), showing short bill and small size of body. Compare with last joint of little finger.

in structure, frequent hollow trees or unused chimneys, to which they attach their shallow nests. The nearly related humming-birds are chiefly natives of tropical America, only a few species extending into the United States. Of these the little, brilliantly colored, and pugnacious ruby throat (*Trochilus colubris*) is the most widely distributed. Its nest, like that of other hummers, is composed of moss and lichens bound together with cobweb and lined with down.

210. **Perching birds** (*Passeres*).—The remaining birds, over six thousand in all, belong to one order, the *Passeres* or perchers. They are characterized by great activity, interesting habits, frequently by exquisite powers of song, and in addition to several other structural arrangements have the feet adapted for perching. Their nesting habits

differ widely, but in every case the young are helpless at the time of hatching, and require the care of the parents.

The perchers constitute the greater number of the birds living in the meadows and woods, and are more or less



FIG. 128.—Anna hummer (*Calypte anna*) on nest.

common, and consequently familiar everywhere. Among the families into which the order is divided that of the fly-catchers (*Tyrannidæ*), the crows and jays (*Corvidæ*), the orioles and blackbirds (*Icteridæ*), the finches and sparrows (*Fringillidæ*), the swallows (*Hirundinidæ*), the warblers (*Mniotiltidæ*), the thrushes, robins, and bluebirds (*Turdidæ*), are the more familiar, though the others are equally interesting.

CHAPTER XVIII

THE MAMMALS

211. **General characteristics.**—The mammals, constituting the last and highest class of the vertebrates, comprise such forms as the opossum and kangaroo, the whales and porpoises, hoofed and clawed animals, the monkeys and man. All are warm-blooded, air-breathing animals, having the skin more or less hairy. The young are born alive, except in the very lowest forms, which lay eggs like reptiles, and for some time after birth are nourished by milk supplied from the mammary glands (hence the word *mammals*) of the mother. The skeleton is firm, the skull and brain within are relatively large, and, with few exceptions, four limbs are present.

Most of the mammals inhabit dry land. A number, however, such as the whales and seals, are aquatic; while others, such as the beavers, muskrats, etc., though not especially adapted for an aquatic life, are, nevertheless, active swimmers, and spend much of their time in the water.

Mammals tend to associate in companies, as we may witness among the ground-squirrels, prairie-dogs, rats, mice, and the seals and whales. In many cases they band for mutual protection, and often fight desperately for one another. Claws, hoofs, and nails are efficient weapons, and spiny hairs, as on the porcupines, bony plates, such as encircle the bodies of the armadillos, and thick skin and hair, serve as a protection. The hair is also frequently colored to harmonize the animal with its surroundings.

Some rabbits and hares in the far north don a white coat in the winter season.

212. **Skeleton.**—As in other vertebrates, the external form of mammals is dependent in large measure upon the internal skeleton. This consists of relatively compact bones, the cavities of which are filled with marrow. Those forming the skull are firmly united, and, as in other vertebrates, afford lodgment for several organs of special sense and for the brain, which, like that of the birds, completely fills the cavity in which it rests. The vertebral column to which the skull is attached differs considerably in length, but it invariably gives attachment to the ribs, and to the basal girdles supporting one or two pairs of limbs. Generally speaking, the number of bones in the head and trunk of all mammals is the same, so the variations we note in the species about us, for example, are simply due to differences of shape and proportion. As we are aware, there is a great dissimilarity between the length of the neck of man and that of the giraffe, yet the number of bones in each is precisely the same. On the other hand, the variations occurring in the limbs are often due to the actual disappearance of parts of the skeleton. Five digits in hand and foot is the rule, and yet, as we well know, the horse walks on the tip of its middle finger and toe, the others being represented by small, very rudimentary, splint bones attached far up the leg. The even-hoofed animals walk on two digits, two smaller hoofed toes being often plainly visible a short distance up the leg, as in the pig. In the whales the hind limbs have completely disappeared, and in the seals, where the fore limbs are modified, as in the whales, into flippers, the hind limbs show many signs of degeneration.

213. **Digestive system.**—Some mammals, such as man, monkeys, and pigs, are omnivorous; others, like the cud-chewers and gnawers, are vegetarians; and still others, like the foxes, weasels, and bears, are carnivorous. In

every case the food substances are acted on by a digestive system constructed on the same general plan as that in man, yet modified according to the specific work it is required to perform. The teeth especially afford a valuable indication of the animal's feeding habits, and, as we may notice later, are also of much value in classification. They consist of incisors used in biting, canines for tearing, and premolars and molars for crushing and grinding.

The remaining portions of the digestive tract, esophagus, stomach, and intestine, with their appended glands, are usually not unlike those possessed by the squirrel (Fig. 1). The chief differences are in the size of the various regions. The stomach, for example, may be long and slender or of great dimensions, and its surface may further be increased by several lobes, which are especially well developed in the ruminants or cud-chewers. The intestine, relatively longer in the mammals than in any other class of vertebrates, also exhibits great differences in length and size. In the flesh-eating species its length is about three or four times the length of the body, while in the ruminants it is ten or twelve times the length of the animal.

214. Nervous system and sense-organs.—As before noted, the nervous system of mammals is characterized by the large size and great complexity of the brain. Even in the simpler species the cerebral hemispheres (large front lobes of the brain, Fig. 1) are well developed, and in the higher forms of the ascending series they form by far the larger part of the brain. The sense-organs also are highly developed, and are constructed and located much as they are in man. The greatest variations occur in the eyes. In some of the burrowing animals they are usually small, and in some of the moles and mice may even be buried beneath the skin and very rudimentary. On the other hand, they are large and highly organized in nocturnal animals; more so, usually, than in those which hunt their prey by day. The ears also have different grades of perfection, which

appear to be correlated with the habits of the animal. Among the species of subterranean habits the sense of hearing is largely deficient; but, on the other hand, it is exceedingly keen in the ruminants, and enables them to detect their enemies at surprisingly great distances. In these creatures the outer ears are of large size and great mobility, and, placed as they are on the top of the head, serve to concentrate the sound-waves on the delicate apparatus within. In the mammals the sense of smell reaches its highest development, especially among the carnivores which scent their prey. On the other hand, it is said to be absent in the whales and very deficient in the seals. The sense of taste, closely related to that of smell, is located in taste-buds on the tongue, and is also more acute than in any other class of animals. The sense of touch, located over the surface of the body, is especially delicate on the tips of the fingers, the tongue, and lips, which often bear long tactile hairs, called whiskers or *vibrissæ*.

215. Mental qualities.—Correlated with the high degree of perfection of the brain and sense-organs the mammals show a higher degree of development of the intellectual faculties than any other class of animals. In many cases their acts are instinctive, and not the result of previous training and experience. Just as the duck hatched in an incubator instinctively takes to the water and pecks at its food, or as the bee builds its symmetrical comb, many of the mammals perform their duties day by day. On the other hand many other mammals are also undoubtedly intelligent. They possess the faculty of memory; they form ideas and draw conclusions; they exhibit anger, hatred, and self-sacrificing devotion for their companions and offspring that is different from that in man only in degree and not in kind. In fact, intelligence differs from instinct primarily in its power of choice among lines of action.

216. Classification.—Of the eleven orders into which the mammals have been divided eight are represented in this



FIG. 129.—Three-toed sloth (*Bradypus*). About one-tenth natural size.

country. Of the other three the first (*Monotremes*) and simplest of the eleven is represented by the duck-mole

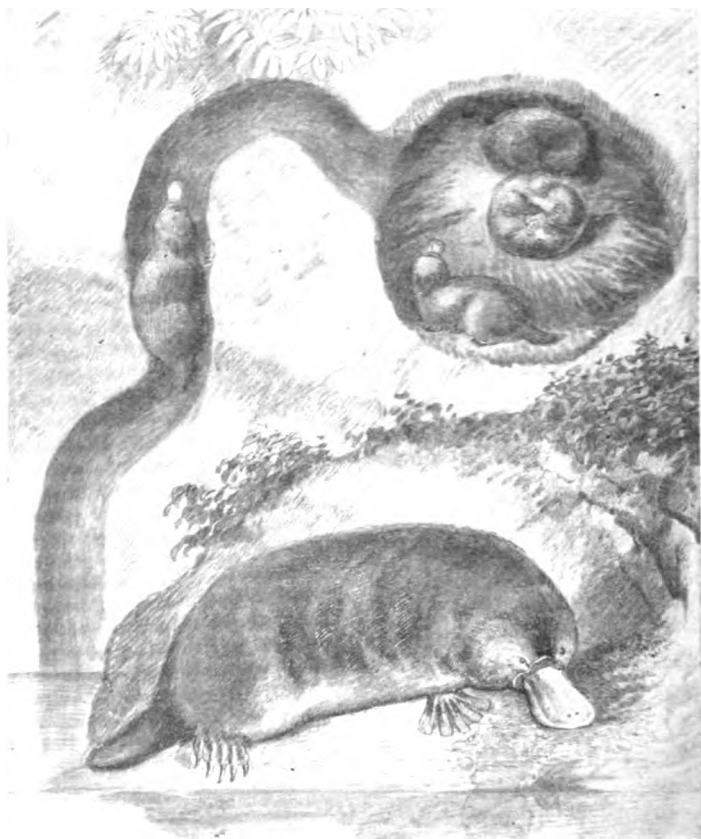


FIG. 139.—Australian duck-mole (*Ornithorhynchus paradoxus*). One-fifth natural size.

(*Ornithorhynchus*) living in the Australian rivers. Its general appearance and mode of life are illustrated in

Fig. 130. The monotremes are the only mammals which lay eggs. One or two eggs are laid in a carefully constructed nest where the young are hatched. Another order (*Edentata*) includes a number of South and Central American forms, among which are the ant-eaters, armadillos, and tree-inhabiting sloths (Fig. 129). Still another order (*Sirenia*) includes the fish-shaped marine dugong and sea-cows or manatees, of which one species is found occasionally on the Florida coast. The remaining orders are described in the succeeding sections.

217. The opossums and kangaroos (*Marsupialia*).—The lowest order of mammals represented in the United States



FIG. 131.—Opossum (*Didelphys virginiana*). One-tenth natural size. Photograph by W. H. FISHER.

is that of the marsupials. It includes the opossums and kangaroos, together with a number of comparatively small and unfamiliar animals living chiefly in and about Australia.

The opossums, fairly abundant throughout the warmer portions of this country, are rat-like creatures, with scaly tails, yellowish-white fur, large head, and pointed snout. Except at the breeding season they lead solitary lives, sleeping in the holes of trees by day and at night feeding on roots, birds, and fruits.

The kangaroos, familiar from specimens in menageries or museums, chiefly inhabit the plains of Australia. The giant gray kangaroos (*Macropus giganteus*), attaining a height of over six feet, go in herds, and owing to the great development of their hind limbs and tails are able, when alarmed, to travel with the swiftness of a horse. Several smaller species, some no larger than rabbits, live among the brush, and like their larger relatives crop the grass and tender herbage with sharp incisor teeth.

While the marsupials do not lay eggs as does the duck-mole, they allow them to develop within the body for a very short time only. Hence the young, when born, are scarcely more than an inch in length, and are blind, naked, and perfectly helpless. At once they are placed by the mother in the pouch of skin, or *marsupium*, on the under side of her body. In this the young are suckled and protected until able to gather their own food and fight their own way.

218. Rodents or gnawers (Glires).—The rodents are a large group of mammals, including such forms as the rats, mice, squirrels, gophers, and rabbits. They are readily distinguished by their clawed feet adapted for climbing or burrowing, and by large curved incisor teeth. Unlike ordinary teeth, they grow continually, and, owing to the restriction of the hard enamel to their front surfaces, wear away behind faster than in front, thus producing a chisel-like cutting edge.

The largest of our native rodents is the porcupine (*Erethizon dorsatus*), which ranges from Maine to Mexico, and attains a length of nearly three feet. Many of the hairs

of the body have the form of stiff, barbed spines (Fig. 132), readily dislodged so that the animal requires no other weapon of defense. The rabbits and hares are of smaller size, and the cottontails especially are widely distributed. West of the Mississippi the jack-rabbits are familiar, and are



FIG. 132.—Porcupine (*Hystrix cristata*). One-tenth natural size.—After BREHM.

famous for their great speed. Like the porcupines, they feed on leaves and grass, and are often very destructive. The mice, especially the field and white-footed mice, are abundant in woodland and meadow throughout the United States. The house-mouse (*Mus musculus*) is a native of Europe, as is the common rat (*M. decumanus*), which was imported over a century ago. The wood-rat (*Neotoma*), however, is native, and may be found in many localities from east to west. The muskrat (*Fiber zibethicus*), beaver (*Castor canadensis*), and woodchuck (*Arctomys monax*) were also more or less plentiful formerly, but in many localities are well-nigh exterminated. The squirrels, on the other hand, continue to exist in large numbers. The prairie-

dogs, ground-squirrels, and chipmunks of the terrestrial species are of frequent occurrence, and of the tree-dwellers the fox, gray and red squirrels are well known in many sections of the United States.

219. Insect-eating mammals (Insectivora).—The shrews and moles belonging to this order are representatives of a large group of small animals, which, unlike the major number of rodents, live on insects. The shrews, of which there are several species in this country, are small, mouse-like creatures, nocturnal in their habits, and hence rarely seen. The moles are of much larger size, and owing to their burrowing proclivities scarcely ever appear above ground, but excavate elaborate burrows with their shovel-like feet, devouring the insects which fall in their way. The common mole (*Scalops aquaticus*) extends from the eastern seaboard to the Mississippi River, where it is replaced by the prairie-mole (*S. argenteus*), which extends far to the west, into a country inhabited by other species.

220. The bats (Chiroptera).—The bats are also insectivorous, but their habits are widely different from those of the shrews and moles. The forearm and the fingers of the fore limbs are greatly elongated, and are connected by a thin papery membrane, which also includes the hind limbs and tail, and serves as an efficient organ of flight. During the day they remain suspended head downward in some dark cranny, awakening at nightfall to capture flying insects. Several species are found in this country, the most common being the little brown bat (*Vespertilio fuscus*), with small, fox-like face, large erect ears, and short olive-brown hair. The red bat (*Lasiurus borealis*) is also plentiful everywhere throughout the United States, and is distinguished from the preceding by its somewhat larger size and long reddish-brown fur.

221. The whales and porpoises (Cete).—The animals belonging to this order, the whales (Fig. 133), porpoises, and dolphins, are aquatic animals bearing a resemblance to fishes

only in external form. The cylindrical body has no distinct neck, the comparatively large head uniting directly with

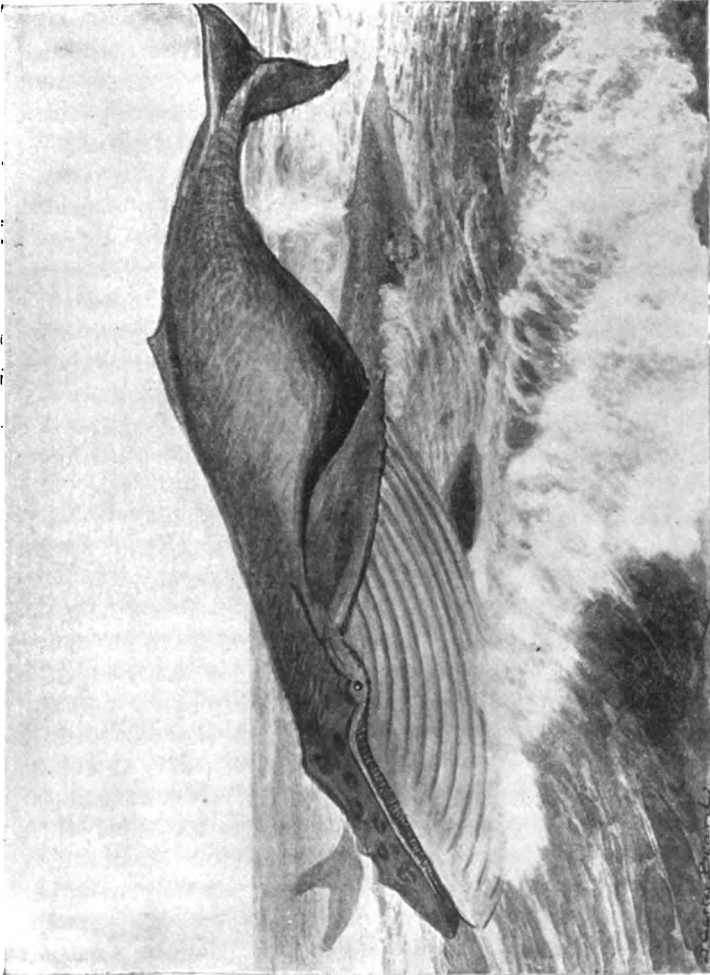


FIG. 133.—Humpback whale (*Megaptera versabilis*). Attains a length of seventy feet.

the cylindrical body, which terminates in the tail with horizontally placed fins. No external signs of hind limbs exist,

while the fore limbs are short and capable of being moved only as a whole. External ears are also absent. The eyes are exceedingly small, those of individuals attaining a length of from fifty to eighty feet, being in some species, at least, but little larger than those of an ox. These are often placed at the corners of the mouth. The nasal openings, often known as blow-holes, are situated on the forehead, and as the whale comes to the surface for air afford an outlet for the stream of breath and vapor often blown high in the air—a process known as spouting. In some of the whales, such as the dolphin, porpoise, and sperm-whales, the teeth persist throughout life, but in most of the larger species they never “cut” the gum, but early disappear, and their place is taken by large numbers of whalebone plates with frayed edges which act as strainers. The smaller-toothed forms (porpoises, dolphins, and several species of grampus) are frequently seen close to the shore, where they are usually actively engaged in capturing fish. On the other hand, the larger species, such as the humpback, right whale, and sulferbottom, not uncommon along our coasts, especially to the northward, live on much smaller organisms. With open mouth these whales swim through the water until they collect a sufficient quantity of jelly-fishes, snails, and crustacea, then closing the mouth strain out the water through the whalebone fringes and swallow the residue.

As noted above, the animals of this order are almost wholly devoid of hair, but the heat of the body is retained by a thick layer of fat beneath the skin. This “blubber” also gives lightness to the body (as do the voluminous lungs), and, furthermore, yields large quantities of oil, which in former times made “whale-fishing” a profitable industry. The whales bear one, rarely two offspring, which are solicitously attended by the mother for a long time. The smaller species grow to a length of from five or eight feet (porpoises, dolphins) to twice this size (grampuses); while the larger whales, by far the largest of animals, range from

thirty to over a hundred feet in length with a weight of many tons.

222. Hoofed mammals (Ungulata).—The order of hoofed animals or ungulates includes a large number of forms like the zebra, elephant, hippopotamus, giraffe, deer, and several other wild species, some of which are domesticated, such as horses, sheep, goats, and cattle. All of these animals walk on the tips of their toes, and the claws have become developed into hoofs. The order is divided into the odd-toed forms (perissodactyls), such as the rhinoceros with three toes and the horse with one, and the even-toed (artiodactyls), as the pigs with four, and the ox, deer, etc., with two toes. The even-toed forms are again divided into those which chew the cud (ruminants) and those which do not (non-ruminants). No living native odd-toed mammal exists in this country, and of the wild even-toed species all are ruminants. In the members of this latter group the swallowed food passes into a capacious sac (the paunch), is thoroughly moistened, and passed into the second division (the honeycomb), later to be regurgitated and ground by the powerful molars. It is then reswallowed, and undergoes successive treatment in the other two divisions of the stomach (the manyplies and reed) before entering the intestine.

Among the North American ruminants, the deer family (*Cervidæ*) is the best represented. In the more unsettled regions of the East the red deer is still common, and the same may be said of the white-tailed, black-tailed, and mule-deer of the West. Among the woods and lakes to the northward live the reindeer and caribou, and the largest of the deer family, the moose, which attains the size of the horse. Of nearly the same size is the wapiti or elk, whose general characters are shown in Fig. 134. In all of the above-mentioned species the horns, if present, are confined to the male (except in the reindeer), and are annually shed after the breeding season.

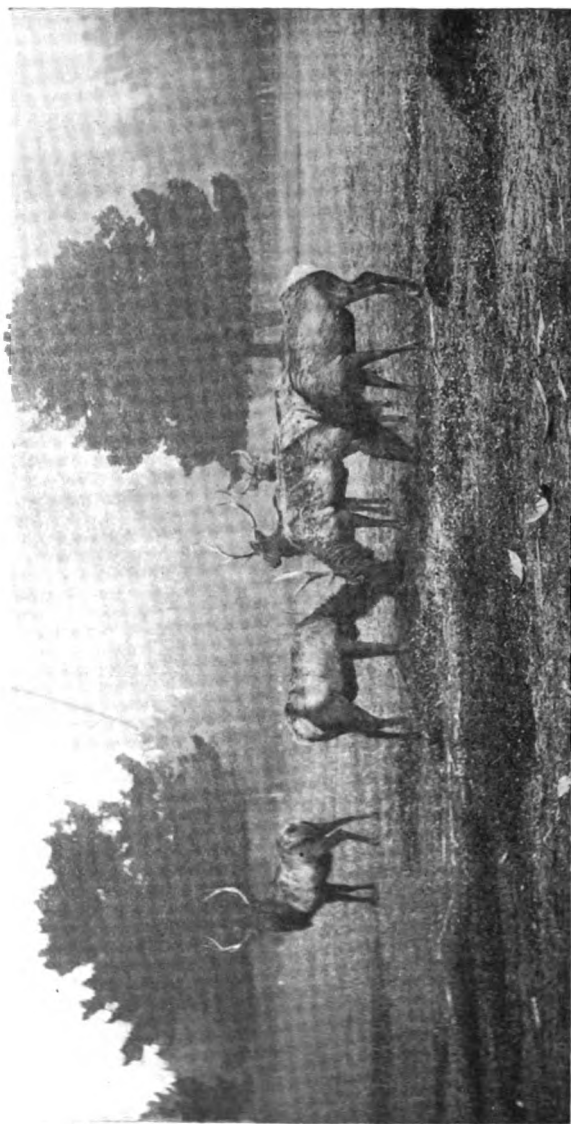


FIG. 184.—American elk (*Cervus canadensis*).

The native hollow-horned ruminants (*Bovidae*) are at present confined to the Western plains, and comprise the pronghorn antelope (*Antilocapra americana*), the wary big-horn or Rocky Mountain sheep (*Ovis canadensis*), living in mountain fastnesses, and the buffalo or bison (*Bison americanus*). All of these species were formerly abundant, especially the pronghorn and buffalo, which roamed the plains by thousands, but their extermination has been nearly complete, small herds only persisting in a few wild, inaccessible regions, or protected in parks.

Our domestic sheep and cattle are probably the descendants of several wild species living in Europe and other portions of the world. Of the domesticated ungulates the horse is the direct descendant of Asiatic wild breeds; while the pig traces its ancestry back to the wild boar (*Sus scrofa*) of Europe, and probably a native species (*S. indicus*) of eastern Asia.

223. Flesh-eating mammals (Ferae).—The order of *Ferae* or Carnivora is typically exemplified by such animals as the lions, tigers, bears, dogs, cats, and seals, forms which differ from all other mammals by the large size of the canine teeth (often called dog-teeth) and the molars, which are adapted for cutting, not crushing. The limbs, terminated by four or five flexible digits, bear well-developed claws, which, together with the teeth, serve for tearing the prey. While the bears shuffle along on the soles of their feet, the greater number of species, as illustrated by the dog and cat, tread noiselessly on tiptoe. Almost all are fierce and bold, with remarkably keen senses and quick intelligence, and are the dreaded enemies of all other orders of mammals.

The largest land-inhabiting carnivora are the bears, of which the brown or cinnamon bear (*Ursus americanus*), inhabiting North America generally where not exterminated, and the huge grizzly (*Ursus horribilis*) of the Western mountains, are the best-known species. The former lives on berries and juicy herbs, while the grizzly prefers

the flesh of animals which it kills. The raccoon (Fig. 135) (*Procyon lotor*) is found in wooded districts all over the United States, and its general appearance and thieving propensities are well known. Almost everything is accept-

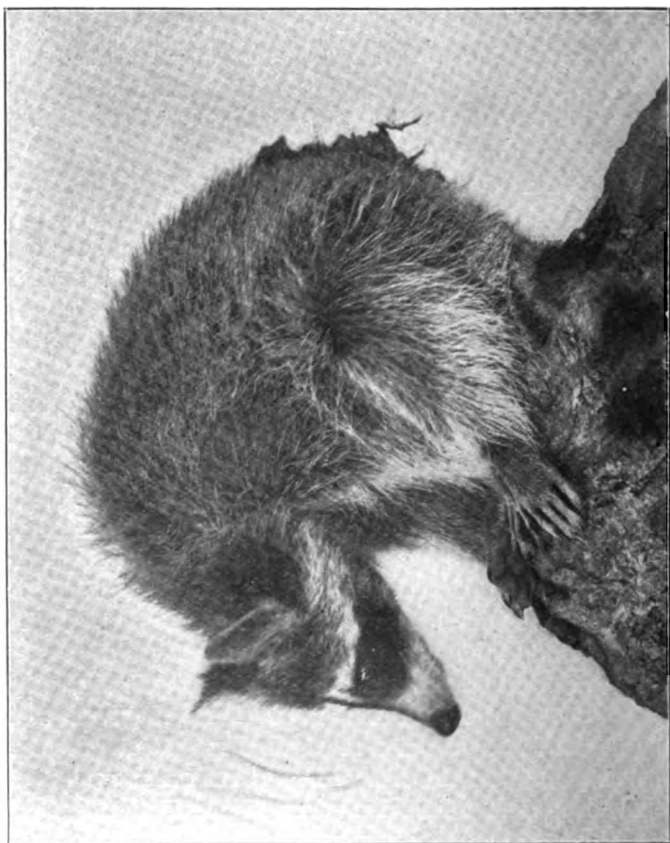


Fig. 135.—Raccoon (*Procyon lotor*). Photograph by R. W. SHUFALDT.

able as an article of food, and its fondness for poultry and vegetables makes it an unmitigated nuisance. The otters, skunks, badgers, wolverenes, sables, minks, and weasels, while differing considerably in general appearance and habits, nev-

ertheless belong to one family (the weasel family, *Mustelidæ*), and are more or less valued for their fur. Almost all are characterized by a fetid odor, especially the skunk, which is notoriously offensive, and in consequence is avoided by all other animals.

The dog family is represented by several widely distributed varieties of the red fox (*Vulpes pennsylvanicus*) and gray fox (*Urocyon cinereo-argentatus*), and by the coyotes



FIG. 136.—Silver fox (*Vulpes pennsylvanicus*, var. *argentatus*). Photograph by W. K. FISHER.

(*Canis latrans*) and wolves (*Canis nubilus*). The domestic dog (*Canis familiaris*) is probably the descendant of the wolf, and owing to man's careful breeding during thousands of years has formed several widely differing varieties.

The cat family, comprising the most powerful, savage, and keenest-scented carnivora, is represented by the lion, tiger, jaguar, and hyena. In this country the group is represented by the lynx (*Lynx canadensis*), the wildcat (*Lynx rufus*), and the panther or puma (*Felis concolor*), which attains the length of nearly five feet. The domestic cat has, like the dog, been domesticated for centuries, and has possibly descended from an African species (*Felis*



FIG. 137.—Panthers (*Felis concolor*) and peccaries (*Dicotyles torquatus*).

caffa), which was held sacred by the Egyptians, who embalmed them by thousands.

224. **Man-like mammals (Primates).**—The last and highest order of mammals, the Primates, includes the lemurs, monkeys, and man. The first of these are strange squirrel-like forms living chiefly in trees in Madagascar and neighboring regions where they feed on insects. The apes and monkeys are divided into Old and New World forms, which differ widely from each other. The American species are marked by flat noses, with the nostrils far apart. All are arboreal, many have long prehensile tails, and the digits bear nails, not claws. Among them are several species of marmosets, the howling monkeys (*Myocetes*), the spider-monkeys (*Ateles*), and the capuchins (*Cebus*), all of which are more or less common in captivity. In the Old World apes, on the other hand, the nostrils are close together and are directed downward, the tail is never prehensile, and in some cases is rudimentary, and may even disappear. The lowest species (the dog-like apes) include the large, clumsy baboons, among them the familiar blue-nosed mandrill (*Cynocephalus maimon*) and several other species of lighter frame, such as the long-tailed monkey (*Cercopithecus*) (Fig. 139), the tailless *Macacus*, common in menageries, and the Barbary ape, inhabiting northern Africa and extending over into Spain.

The remaining anthropoid or man-like apes include the gibbons (*Hylobates*), orang-utan (*Simia*), gorilla (*Gorilla*), and chimpanzee (*Anthropo-*



FIG. 138.—Baby orang-utan. From life.



FIG. 139.—A monkey (*Cercopithecus*) in a characteristic attitude of watchfulness.

pithecus). The gibbons, inhabiting southeastern Asia, possess arms of such length that they are able to touch their hands to the ground as they stand erect. They are thus adapted for a life in the trees, where they spend most of their time feeding on fruit, leaves, and insects. In the same district the orang occurs, walking when on the ground on its knuckles and the sides of its feet. It prefers the life in the trees, however, in which it builds nests serving for rest and concealment. The gorilla (Fig. 140), the largest of apes, attaining a height of over five feet and a weight of two hundred pounds, is a native of Africa, where it lives in families and subsists on fruits. The same region is the home of the chimpanzee, which in its various characteristics approaches most nearly to man.

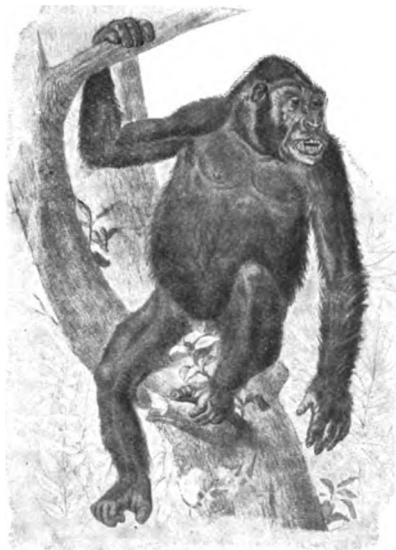


FIG. 140.—Gorilla (*Gorilla*).

Man (*Homo sapiens*) is distinguished by the inability to oppose the big toe as he does his thumb—a feature associated with his erect position—and by the relatively enormous size of the brain. Even in an average four-year-old child or an Australian bushman the brain is twice as large as in the gorilla. With this relatively great development of the nervous system is correlated superior mental faculties, which together with social habits and powers of speech exalt man to a position far above the highest ape.

As usually understood, the family of man (*Hominidae*) contains but a single species, cosmopolitan and highly variable. This species is "now split up into many subspecies or races, the native man of this continent, or 'American, Indian,' being var. *americanus*. Other races now naturalized in America are: the Caucasian race, var. *europæus*; the Mongolian race, var. *asiaticus*; and the negro race, *afër*. The first of these is an immigrant from Europe, the second from Asia, and the third was brought hither from Africa by representatives of var. *europæus* to be used as slaves."

CLASSIFICATION OF ANIMALS

The following table of classification is designed to show the systematic position of the more important animals mentioned in the text.

ANIMAL KINGDOM

ONE-CELLED ANIMALS:

BRANCH I. **PRŌTŌZO'A** (*protos*, first; *zoon*, animal)

Class I. **Rhisop'oda** (*rhiza*, root; *pous*, foot).

Amœ'ba, *Diſflū'gia*.

Class II. **Infusō'ria** (organisms found in infusions).

Order 1. **Flagellā'ta** (*flagellum*, a whip).

Euglēm'a, *Cōdōsig'a*, *Pāndōrī'na*, *Vōl'vœ*.

Order 2. **Ōlīā'ta** (*cilium*, an eyelash).

Pāramœ'cium, *Vorticē'l'a*.

MANY-CELLED ANIMALS (*Metasoa*):

BRANCH II. **PORĪF'ERA** (*porus*, pore; *fero*, to carry)

Class I. **Porifera** (or sponges).

BRANCH III. **ŌHLĒNTĒRĀ'TA** (animals with combined body and stomach cavity)

Class I. **Hýdrosō'a** (*hydra*, water-serpent; *zoon*, animal).

Hý'dra, *Gōnionē'mus*, *Hýdrāctīn'ia*, Portuguese man-of-war.

Class II. **Scōphosō'a** (*scyphos*, cup; *zoon*, animal).

Rhīsō's'toma, *Hāliclŷ's'tus*.

Class III. **Actīnōzo'a** (*actis*, a ray; *zoon*, animal).

BRANCH IV. **PLĀTYHĒLMĪN'THES** * (*platus*, flat; *helminthos*, a worm)

Class I. **Plātō'da** (*platus*, flat; *eidos*, likeness).

Plānā'ria, *Lēptōplā'na*.

* For purposes of convenience, the flatworms (Platyhelminthes), roundworms (Nematelminthes), and segmented worms (Annelids) are combined in one branch (The Worms) in the text.

Class II. **Trémató'da** (*trematodes*, pierced with holes, from the erroneous belief that the suckers are holes into the body).

Liver fluke, *Epidél'la*.

Class III. **Oštó'da** (*cestos*, a girdle; *eidos*, likeness).

Tapeworm.

BRANCH V. **NEMATELMINTHES** (*nema*, thread; *helminthos*, a worm)

Class I. **Némató'da**.

Vinegar eel (*Anguillula*), *Tríkh'na*, horsehair snake (*Górdius*).

BRANCH VI. **NÉMERTÍN'EA** (*nemertes*, a sea-nymph)

BRANCH VII. **ROTÍ'ERA** (*rota*, a wheel; *fero*, to carry)

BRANCH VIII. **ANNÉL'IDA** (*annelus*, a ring)

Class I. **Chætóp'oda** (*chaite*, bristle; *pous*, foot).

Order 1. **Polychæ'te** (*polus*, many; *chaite*, bristle).

Ner'eis, *Polynó'e*, *Sér'pula*, *Sabél'la*.

Order 2. **Oligóchæ'te** (*oligos*, few; *chaite*, bristle).

Earthworm (*Lüm'brícus*).

Class II. **Hírudín'ea** (*hirudo*, a leech).

Leeches.

Class III. **Géphyrea** (*gephura*, a bridge, because these animals were once supposed to bridge the gap between the worms and sea-cucumbers).

BRANCH IX. **MÖLLUSCOIDA**

Class I. **Pólyzó'a** (*polus*, many; *zoon*, animal—colonial animals).

Polyzoa, sea-mats.

Class II. **Bráchióp'oda** (*brachion*, arm; *pous*, foot).

Lamp-shells (brachiopods).

BRANCH X. **MÖLLÜS'CA** (*mollis*, soft)

Class I. **Láméllibranchiá'ta** (*lamella*, a plate; *branchia*, gill).

Clams, mussels, oysters, ship-worm (*Terš'do*).

Class II. **Gastróp'oda** (*gaster*, stomach; *pous*, foot).

Snails, slugs, armadillo snails, naked snails, nudibranchs.

Class III. **Oéphalóp'oda** (*cephale*, head; *pous*, foot).

Squids, cuttlefishes, devil-fishes (*Oc'tópus*), nautilus.

BRANCH XI. **ÉCHINÓDĚR'MATA** (*echinos*, a hedgehog; *derma*, skin)

Class I. **Asterol'dea** (*aster*, star; *eidos*, likeness).

Starfishes.

- Class II. **Ophiuroi'dea** (*ophis*, serpent; *oura*, tail; *eidos*, likeness).
Serpent- or brittle-stars, basket-stars.
- Class III. **Holothuroi'dea** (*holothurion*, a kind of water polyp; *eidos*, likeness).
Sea-cucumbers.
- Class IV. **Crinoi'dea** (*crinon*, lily; *eidos*, likeness).
Sea-lilies or crinoids.
- Class V. **Echinoi'dea** (*echinos*, hedgehog; *eidos*, likeness).
Sea-urchins.

BRANCH XII. **ARTHRŌP'ODA** (*arthron*, joint; *pous*, foot)

- Class I. **Crustā'oea** (*crusta*, a crust or shell).
Fairy-shrimp (*Brānchīp'us*), water-fleas (*Daph'nia*), cōp'epod, *Cy'clops*, goose barnacle, acorn barnacle, *Sācculī'na*, opossum-shrimp, prawn, lobster, crayfish, cancer-crab, rock-crab, pill-bug or i'sopod, sand-hopper or amphi'pod.
- Class II. **Ōnyoōph'ora** (*onyx*, claw; *phero*, to carry).
Pērtip'atus).
- Class III. **Myriōp'oda** (*myrios*, numberless; *pous*, foot).
Cent'ipede, thousand-legs.
- Class IV. **Inseċ'ta** (*insectum*, cut in, owing to the grooves surrounding the body).
Fishmoth, springtail, cockroach, grasshopper, cricket, katydid, locust, dragon-fly, caddis-fly, may-fly, white ants or termites, ant-lion, water-boatman, water-bug, back-swimmer, chinch-bug, squash-bug, lice, plant-lice, *Phyllōx'era*, scale-insect, gnat, mosquito, flea, house-fly, stag-beetle, wood-beetle, water-beetle, potato-beetle, ladybug, firefly, moth, butterfly, ants, honey-bees and bumblebees, wasps, hornets, yellow-jackets.
- Class V. **Arāch'nida** (*arachne*, spider).
Garden-spider, tārān'tula, bird-spider, trap-door spider, mite, tick, king-crab or horseshoe crab.

BRANCH XIII. **CHORDATA** (*chorda*, a cord, referring to the notochord)

SUBBRANCH I. **Adelochor'da**. Class **Adelochorda**.

SUBBRANCH II. **Urochor'da**. Class **Urochorda**.

Sea-squirts, Tunicā'ta, Ascīd'ians.

SUBBRANCH III. **Vertebrā'ta** (*vertebratus*, jointed).

Division A. Acrā'nia (*a*, without; *cranium*, skull). Class **Lepto-cardii**.

Lancelet (*Brānchiōs'toma* = *Amphiox'us*).

Division B. Crāniā'ta.

Class I. *Cyclostōm'ata* (*cyclos*, circle; *stoma*, mouth).

Hagfishes, lamprey.

Class II. *Pis'ces* (*piscis*, fish).

Shark, skate or ray, lung-fish, sturgeon, garpike, catfish, horned pout, bullhead, carp, dace, chub, minnow, eel, herring, shad, salmon, trout, pike, stickleback, blindfish, sea-horse, mullet, flying-fish, perch, darter, sunfish, sea-bass, mackerel, snapper, grunt, weakfish, bluefish, rose-fish, gurnard, sculpin, codfish, flounder, angler.

Class III. *Amphib'ia* (*amphi*, double; *bios*, life).

Siren, mud-puppy, water-dog, tiger salamander, axolotl, toad, frog, tree-frog.

Class IV. *Reptil'ia* (*reptans*, creeping).

Skink, "glass-snake," swift, chameleon, horned toad, Gila monster, blacksnake, grass-snake, milk-snake, rattlesnake, copperhead, water-moccasin, soft-shell turtle, snapper, painted turtle, box-turtle, leather-turtle, loggerhead, hawkbill, crocodile, alligator.

Class V. *A'ves* (*avis*, bird).

Ostrich, loon, grebe, auk, murre, puffin, gull, tern, petrel, albatross, cormorant, pelican, duck, goose, swan, heron, bittern, crane, rail, mud-hen or coot, snipe, woodcock, sandpiper, kill-dee plover, quail, grouse, wild turkey, prairie-chicken, pigeon, dove, eagle, hawk, owl, turkey-buzzard, cuckoo, kingfisher, woodpecker, sapsucker, swift, humming-bird, night-hawk, whippoorwill, crow, jay, swallow, warbler, thrush, robin, bluebird.

Class VI. *Mammāl'ia* (*mamma*, breast).

Duck-mole, ant-eater, sloth, armadillo, sea-cow, opossum, kangaroo, porcupine, mouse, rat, muskrat, woodchuck, beaver, rabbit, squirrel, chipmunk, prairie-dog, shrew, mole, bat, whale, grampus, dolphin, porpoise, zebra, elephant, giraffe, deer, antelope, goat, sheep, horse, cow, pig, buffalo, bear, raccoon, otter, skunk, badger, wolverene, sable, mink, weasel, dog, fox, wolf, cat, lynx, panther, monkey, ape, baboon, gibbon, orang-utan, gorilla, chimpanzee, man.

INDEX

- Acipenser sturio* (illus.), 162.
 Acorn-barnacle (illus.), 97.
 Air-bladder, 155.
 Albatross, 212.
Alligator mississippiensis (illus.), 191.
 Alternation of generations, 35.
 Altricial, 208.
Amæba (illus.), 12; structure and habits, 12.
Amæba-like protozoa, 12.
 Amphibian, development of, 174; distribution, 178; anatomy and habits, 179.
 Amphibious (*amphi*, double; *bios*, life), 176.
 Amphioxus (illus.), 157.
 Amphipod (illus.), 106.
 Anatomy (*anatemno*, to cut up), defined, 1.
 Angler (illus.), 169.
 Angle-worm (illus.), 55.
Anguillula aceti (illus.), 53.
 Animals, characteristics of, 2; simple and complex, 18.
 Animals and plants compared, 2.
 Annelids, 55.
Anosia plexippus (illus.), 125.
 Ant, 128; white (illus.), 120.
 Anteater, 231.
Antedon (illus.), 148.
 Antelope, 239.
 Ant-lion (illus.), 120.
 Apes, 243.
 Arachnida, characteristics of, 188.
Archæopteryx, 201.
Argynnis cybele (illus.), 126.
Ariolimax columbianus (illus.), 81.
 Armadillo, 231.
 Arthropods, general features of, 93.
 Ascidian (illus.), 152.
 Asexual reproduction, 31.
Asterias ocracea (illus.), 141.
Astrophyton (illus.), 143.
 Auk, 209.
 Axolotl, 183.
 Back-swimmer, 121.
 Balancers, 122.
 Band-worm (illus.), 70.
 Barnacles (illus.), 96.
Bascanion constrictor (illus.), 187.
 Basket-star (illus.), 141.
 Bass, 166.
 Bat, brown, 234; red, 234.
 Bear, 239.
 Beaver, 232.
 Bees, 238.
 Beetles, 124.
 Bell animalcule (illus.), 16.
 Bilateral symmetry, 44.
 Biology (*bios*, life; *logos*, a discourse) defined, 1.

- Birds, characteristics of, 201; anatomy of, 204; habits of, 207.
 Bird spider, 186.
 Bittern, 215.
 Black-snake (illus.), 193.
 Blastula (illus.), 21.
Bombus (illus.), 130.
 Bony fish (illus.), 160.
 Botany, defined, 1.
 Brachiopod (illus.), 70.
Bradypus tridactylus (illus.), 229.
Branchiostoma californiense (illustration), 157.
Branchipus (illus.), 94.
 Brittle-star (illus.), 141; regeneration of, 145.
 Bugs, 121.
 Bumblebee (illus.), 130.
 Butterflies, 125.
 Buzzard, 219.
 Byssus, 77.

 Caddis-fly, 119.
Calcolynthus primigenius (illus.), 25.
Calypte anna (illus.), 224.
Cancer productus (illus.), 104.
Caprella (illus.), 106.
 Carapace, of crustacea, 95, 99; of turtle, 188.
 Carp, 163.
 Cat, domestic, 239; wild, 239.
 Catfish, 163.
 Cell (*cella*, a little room), 7; shape and size, 7; typical (illus.), 8.
 Centipeds (illus.), 111.
 Cephalopod (illus.), 87.
 Cephalothorax, 99.
Cercopithecus (illus.), 244.
Cervus canadensis (illus.), 238.
 Cestode (illus.), 50.
 Cete, 234.

 Cheiroptera, 234.
 Chelonia, 188.
 Chinch-bug, 122.
 Chiton (illus.), 82.
Chologaster avelus (illus.), 164; *C. agassizi* (illus.), 164.
 Chordate, characteristics of, 151.
Chordeiles virginianus (illus.), 222.
 Chub, 163.
 Cilium (*cilium*, an eyelash), 16.
 Circulatory system, use of, 4.
 Clam (illus.), 72; anatomy, 72, 78; rock- and wood-boring, 75.
 Clitellum, 58.
 Coccyges, 220.
 Cockroach, 118.
 Coelenterates, general characteristics of, 18.
 Coleoptera (illus.), 124.
 Columbæ, 210.
 Complex animals, characteristics of, 18.
 Compound eyes, 109.
 Coot, 215.
 Copperhead, 193.
 Corals (illus.), 41.
 Cormorant, 212.
 Correlation of function and structure, 6.
 Cottontail, 233.
 Courting colors, 203.
 Crab, hermit (illus.), 102; cancer (illus.), 103; rock (illus.), 104; fiddler, 104.
 Crane (illus.), 215.
 Crayfish (illus.), 101.
 Cricket, 118.
 Crinoid (illus.), 143.
 Crocodile, 190.
 Crocodilia (illus.), 190.
Crotalus adamanteus (illus.), 222.

- Crustacea, 98; anatomy of, 98, 107; multiplication of, 98, 110.
- Cteniza* (illus.), 137.
- Cuckoo, 220.
- Cucumaria* (illus.), 146.
- Cuticle, 14.
- Cuttlefish, 87.
- Cutworm, 112.
- Cyclops (illus.), 95; anatomy of, 98.
- Cyclostomes, 157.
- Daddy-long-legs, 130.
- Decapods, 102.
- Deer, 222.
- Dendrostoma* (illus.), 68.
- Devil-fish (illus.), 87.
- Didelphys virginiana* (illus.), 231.
- Diemyctylus torosus* (illus.), 182.
- Digestive tract, use of, 3.
- Diptera (illus.), 119.
- Division of labor, 21.
- Dog, 223.
- Dolphin, 221.
- Dove, 205.
- Dragon-fly (illus.), 118.
- Duck-mole (illus.), 216.
- Ducks (illus.), 200.
- Eagle, golden, 205; bald (illus.), 205.
- Earthworm (illus.), 55; anatomy, 55; distribution, 59.
- Echinoderms, 141; locomotor system, 146; development of, 150.
- Ecology, 1.
- Eel, 163.
- Egg, fertilization of, 20, 21.
- Elk (illus.), 222.
- Encystment of protozoa, 13.
- Epialtus productus* (illus.), 104.
- Epidella squamula* (illus.), 49.
- Eretmochelys imbricata* (illus.), 195.
- Esox* (illus.), 165.
- Euglena* (illus.), 17.
- Eurypelma lentzii* (illus.), 136.
- Fairy shrimp (illus.), 94.
- Felis concolor* (illus.), 242.
- Feræ, 239.
- Firefly, 124.
- Fish, general characters of, 154; respiration, 155; anatomy, 168; breeding habits, 171.
- Fishmoth, 117.
- Fish-worm (illus.), 55.
- Flagellum (*flagellum*, a whip), 14.
- Flea, 122.
- Flicker, 221.
- Flies, 122; development of, 123.
- Flounders, 168.
- Fox (illus.), 241.
- Frog, 178.
- Gammarus* (illus.), 106.
- Gallinæ, 217.
- Ganglion (*ganglion*, a swelling), a swelling of the nerve-cord due to the accumulation of nerve-cells, 79.
- Ganoidea, 161.
- Garpike, 161.
- Garter-snake, 193.
- Gastropod (illus.), 80; anatomy and physiology, 81.
- Gastric mill (illus.), 107.
- Gastrula (diminutive of *gaster*, stomach), 21.
- Geese, 213.
- Gelasimus* (illus.), 104.
- Gephyrean worms (illus.), 67.
- Gila monster (illus.), 193.
- Glass-snake, 191.

- Glires, 232.
 Gnat, 122.
Gonionemus vertens (illus.), 34.
 Goose barnacle (illus.), 96.
 Gordius, 54.
 Gorilla (illus.), 245.
 Grasshopper (illus.), 117.
 Grebe, 209.
 Green gland, 108.
 Grouse, 218.
Grus americana (illus.), 212.
 Gull, 211.

 Habitat (*habitare*, to dwell), 45.
 Hagfish, 157.
Halætus leucocephalus (illus.), 220.
Halicystus (illus.), 39.
 Harvestman, 185.
 Hawks, 219.
Helix (illus.), 81.
Heloderma suspectum (illus.), 192.
 Hemiptera, 121.
Heptacarpus brevirostris (illus.), 101.
 Hermit-crab (illus.), 102.
 Herodines, 215.
 Herons, 215.
 Herring, 162.
Homo sapiens, 245.
 Honey-bee, 130.
 Hocfed animals, 237.
 Horned toads, 192.
 Hornet, 132.
 Horse-fly (illus.), 119.
 Horsehair-snake, 54.
 Horseshoe-crab (illus.), 139.
 Humming-bird (illus.), 222.
Hydra, structure of, 29; multiplication of, 31; regeneration of, 51.
Hydractinia (illus.), 36, 108.

 Hydranth, 33.
 Hydrozoa, 34; regeneration of, 51.
 Hymenoptera (illus.), 128.
Hystrix cristata (illus.), 233.

 Incubation (*incumbo*, to rest upon), 207.
 Infusoria, 17.
 Insectivora, 234.
 Insects, numbers, 114; anatomy, 115; respiration, 117.
 Isopod (illus.), 101.

 Jelly-fish, of Hydrozoa, 33; of Scyphozoa, 37.
 Julius (illus.), 112.

 Kangaroo, 232.
 Katydid, 117.
 Keyhole-limpet, 82.
 King-crab (illus.), 139.
 Kingfisher, 221.

 Lacertilia, 185.
 Lamellibranch (illus.), 72.
 Lamelliostres, 213.
 Lamprey (illus.), 157.
 Lamp-shell (illus.), 70.
 Lancelet (illus.), 157.
 Lasso-cell, 30.
 Leeches (illus.), 63; haunts and habits, 64.
 Lemur, 243.
Lepas (illus.), 99.
 Lepidoptera (illus.), 125.
Lepomis megalotis (illus.), 167.
Leptoplana (illus.), 45.
 Lice, 122.
 Life histories and race histories, 27.
 Limicolæ, 216.
Limulus polyphemus (illus.), 139.

- Littorina*, habits of, 83.
 Liver-fluke, 49.
 Lizard (illus.), 185.
 Lobster, 102.
 Locust (illus.), 117.
 Long-horned borer beetle (illus.), 124.
 Longipennes, 211.
 Loon, 209.
Lophius piscatorius (illus.), 169.
Lophortyx californicus (illus.), 217.
Lumbricus terrestris (illus.), 55.
 Lung-fish, 160.
 Lynx (illus.), 241.

Macrobdella (illus.), 63.
 Macrocheira, 222.
 Mammals, characteristics of, 225; anatomy, 226; classification, 228.
 Man, 245.
 Many-celled animals, 11.
 Marsupialia, 231.
 Marsupium (*marsupium*, a purse or bag), 232.
 May-fly, 118.
Megaptera versabilis (illus.), 235.
 Mesenteric filaments, 40.
 Messmates, defined, 48.
 Metamorphosis, retrograde, 99; incomplete, 126; complete, 128.
 Metazoa, defined, 11.
 Mice, 233.
 Millipeds (illus.), 111.
 Minnow, 163.
 Mite (illus.), 138.
 Mole, 234.
 Mollusks, general characters of, 72.
 Molt, of crustacea, 99, 110; of birds, 202.
 Monarch butterfly (illus.), 125.
 Monkeys, 243.
 Morphology, defined, 1.

 Mosquito, 122; development of, 123.
 Moths (illus.), 125.
 Mud-hen, 215.
 Mud-puppy (illus.), 178.
 Multiplication of animals, 5.
 Muscle-cell (illus.), 7.
 Muscular system, use of, 4.
 Mussel, 77.
Mysis americana (illus.), 100.
Mytilus edulis (illus.), 77.

 Nauplius (illus.), 99.
 Nematoda (illus.), 52.
 Nemertean worm (illus.), 70.
Nereis (illus.), 59.
 Nerve-cell (illus.), 7.
 Nettle-cell (illus.), 30.
 Neuroptera, 118.
 Newt (illus.), 178.
 Night-hawk (illus.), 222.
 Notochord, 151.
 Nucleus (illus.), 9.

Octopus punctatus (illus.), 87.
 Oligochaetes, 59.
 Operculum (*operculum*, a lid), 87.
 Opossum (illus.), 231.
 Opossum-shrimp (illus.), 100.
 Orang-utan (illus.), 243.
 Orb-weaving spider, 136.
Ornithorhynchus paradoxus (illustration), 230.
 Orthoptera, 117.
 Ostrich (illus.), 209.
 Oyster, 77.
 Owls, 219.

Pagurus bernhardus (illus.), 103.
 Paludicolæ, 215.
Pandorina (illus.), 19.
 Panther (illus.), 241.

- Paramæcium* (illus.), 15.
 Parapodium (*para*, alongside of; *pous*, foot), 60.
 Parasitism, 48.
 Passeres, 223.
 Pelican (illus.), 212.
Pelicanus erythrorhynchus (illus.), 212.
Perca flavescens (illus.), 155.
 Perch, 166.
 Perching birds, 223.
Peripatus eiseni (illus.), 111.
 Pheasant, 217.
Physalia (illus.), 37.
 Physiology (*physis*, the nature of a thing; *logos*, a discussion), 1.
 Pici, 221.
 Piddock (illus.), 75.
 Pigeons, 218.
 Pike (illus.), 164.
 Pill-bug (illus.), 105.
 Pineal gland, 198.
Planaria (illus.), 45.
 Plants and animals, differences between, 1.
 Plants, characteristics of higher, 2.
 Plant-lice, 122; in ant-nests, 129.
 Plastron, 188.
 Plover, killdeer, 216.
 Polychætes, 59; sedentary (illus.), 61; development of, 63.
Polynæ brevisetosa (illus.), 61.
 Polyzoa (illus.), 68.
Porcellio scaber (illus.), 105.
 Porcupine (illus.), 232.
 Porpoise, 234.
 Portuguese man-of-war (illus.), 86.
 Prairie-dog, 233.
 Prawn (illus.), 100.
 Precocial birds, 208.
 Primates, 243.
 Proboscis, of flatworms, 46,
- Procyon lotor* (illus.), 240.
 Protoplasm (*protos*, first; *plasma*, anything molded), 9; structure of, 10.
 Protozoa, 11; characteristics of, 17; colonial, 19.
Pugettia richii (illus.), 104.
 Pulsating vacuoles, 16, 17.
 Pygopodes, 209.
 Quail (illus.), 217.
 Rabbit, 233.
 Raccoon (illus.), 240.
 Race histories and life histories, 27.
 Radial symmetry, 44.
 Rail, 215.
 Rain-crow, 220.
 Raptores, 219.
 Rat, house, 233; wood-, 233; musk-, 233.
 Ratitæ, 209.
 Rattlesnake (illus.), 191.
 Recognition-marks, 203.
 Regeneration, 51.
 Reproduction, sexual and asexual, 5, 32.
 Reptiles, general characteristics, 185; distribution, 191; anatomy, 195.
 Retrograde metamorphosis, 99.
 Rotifer (illus.), 66.
 Ruminant, 237.
Sabella, 62.
 Salamander (illus.), 176; distribution, 178; structure of, 179.
 Salmon, 163.
 Sand-dollar (illus.), 142.
 Sandhopper (illus.), 105.
 Sandpiper, 216.
 Sapsucker, 221.

- Sarcoptes scabiei* (illus.), 138.
Scelophorus undulatus (illus.), 185.
 Scorpion (illus.), 134.
 Scyphozoa, 37; development of, 38.
 Sea-anemone, 40.
 Sea-cucumber (illus.), 143; regeneration of, 145.
 Sea-lily (illus.), 143.
 Sea-mat (illus.), 68.
 Sea-urchin (illus.), 141.
 Sea-squirt (illus.), 152.
 Sedentary life, effect of, 62.
 Segments, of worms, 55; of arthropods, 94.
 Segmented worms, 55.
 Serpentes, 186.
 Serpent-star (illus.), 141.
Serphus dilatatus (illus.), 122.
Serpula (illus.), 62.
 Serpulids, 62.
 Seta, 55.
 Sexual reproduction, 32.
 Shark (illus.), 159.
 Shell-gland, 108.
 Shipworm, 75.
 Shrew, 234.
 Shrimp, fairy, 94; opossum (illus.), 100.
 Silk-moth (illus.), 127.
 Silver-spot butterfly (illus.), 126.
 Simple animals, characteristics of, 18.
 Single-celled animals, 11.
 Sinus, blood, 78.
 Siren (illus.), 178.
 Slug (illus.), 80.
 Snail, common (illus.), 80; armadillo (illus.), 82; naked (illus.), 82.
 Snakes, 186; distribution of, 193.
 Snipes, 216.
Somateria dresseri (illus.), 214.
 Species, origin of, 91.
 Sperm-cell, 20.
Sphenodon punctatus (illus.), 199.
 Spicule, of sponge (illus.), 26; of coral, 42.
 Spiders, organization of, 185; habits, 186.
 Spinnerets, 185.
 Spiny-rayed fishes, 166.
 Sponge, development of (illus.), 21; distribution, 22; shape and structure, 23.
 Spontaneous generation, 54.
 Springtail, 117.
Squalus acanthias (illus.), 159.
 Squash-bug, 122.
 Squid (illus.), 87.
 Squirrels, 233.
 Starfish (illus.), 140; regeneration, 145; structure, 146.
 Steganopodes, 212.
 Stickleback, 164.
 Structure and function, correlation of, 6.
Strongylocentrotus purpuratus (illustration), 144.
Struthio camelus (illus.), 210.
 Sturgeon (illus.), 161.
 Sunfish (illus.), 166.
 Symmetry, radial and bilateral, 44.
 Swan (illus.), 213.
 Swift, 222.
Tænia solium (illus.), 51.
 Tapeworm (illus.), 50; development, 51; in relation to regeneration, 51.
 Tarantula (illus.), 137.
 Teeth, use of, 2.
 Teleostei, 160.
 Termites (illus.), 120.
 Tern, 211.
Terrapene carolina (illus.), 189.

- Thousand-legged worms (illus.), 111.
 Threadworms (illus.), 52.
 Thysanura, 117.
 Tick, 138.
 Tiger salamander, 178.
 Toad (illus.), 178.
 Trap-door spider (illus.), 137.
 Trematode (illus.), 48; development, 51.
Trichina spiralis (illus.), 53.
 Trigger hair, 31.
 Turkey, 218.
 Turtles, 188; structure, 189; distribution, 194.
Typhlichthys subterraneus (illus.), 163.
 Ungulata, 237.
 Vacuole, pulsating, 16; use of, 17.
 Velum (illus.), 35.
Vespa, nest of (illus.), 131.
 Vinegar eel (illus.), 53.
Volvox (illus.), 19; multiplication of, 20.
 Vertebrates, characteristics of, 145; classification, 143.
Vorticella (illus.), 16.
Vulpes pennsylvanicus (illus.), 241.
 Wasps, 128; habits of, 131.
 Water-boatman, 121.
 Water-bug (illus.), 121.
 Water-dog (illus.), 178.
 Water-flea, 95.
 Whale, humpback (illus.), 235; sperm, 236.
 Whale lice, 107.
 Wheel-animalcule (illus.), 66.
 Wheel-weaving spiders, 136.
 Whippoorwill, 222.
 White ant (illus.), 120.
 Wood-beetle (illus.), 124.
 Woodchuck, 233.
 Woodcock, 216.
 Woodpeckers, 221.
 Worms, general characters of, 44; classification, 45.
 Yellowhammer, 221.
 Yellow-jacket, 132.
Zirphæa crispata (illus.), 76.
 Zoology, 1.
 Zoophyte, 29.

(7)

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